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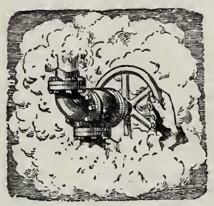

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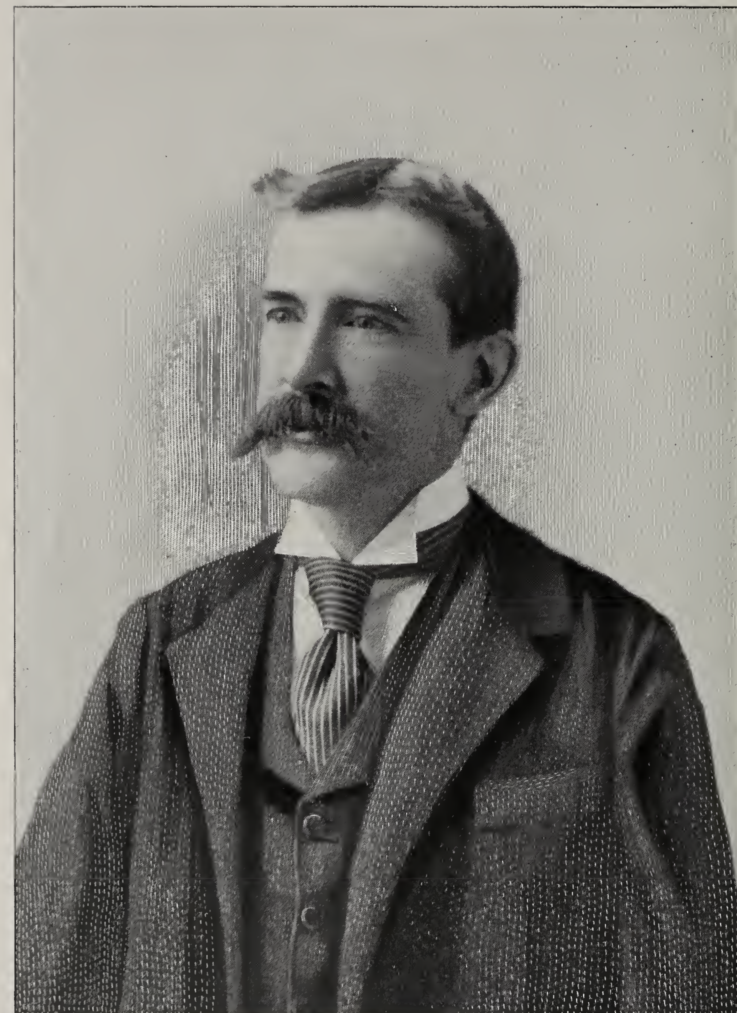

PHOTO BYALLEN, BOSTON

Henry M. Howe

(SEE PAGE 87)

CASSIER'S MAGAZINE

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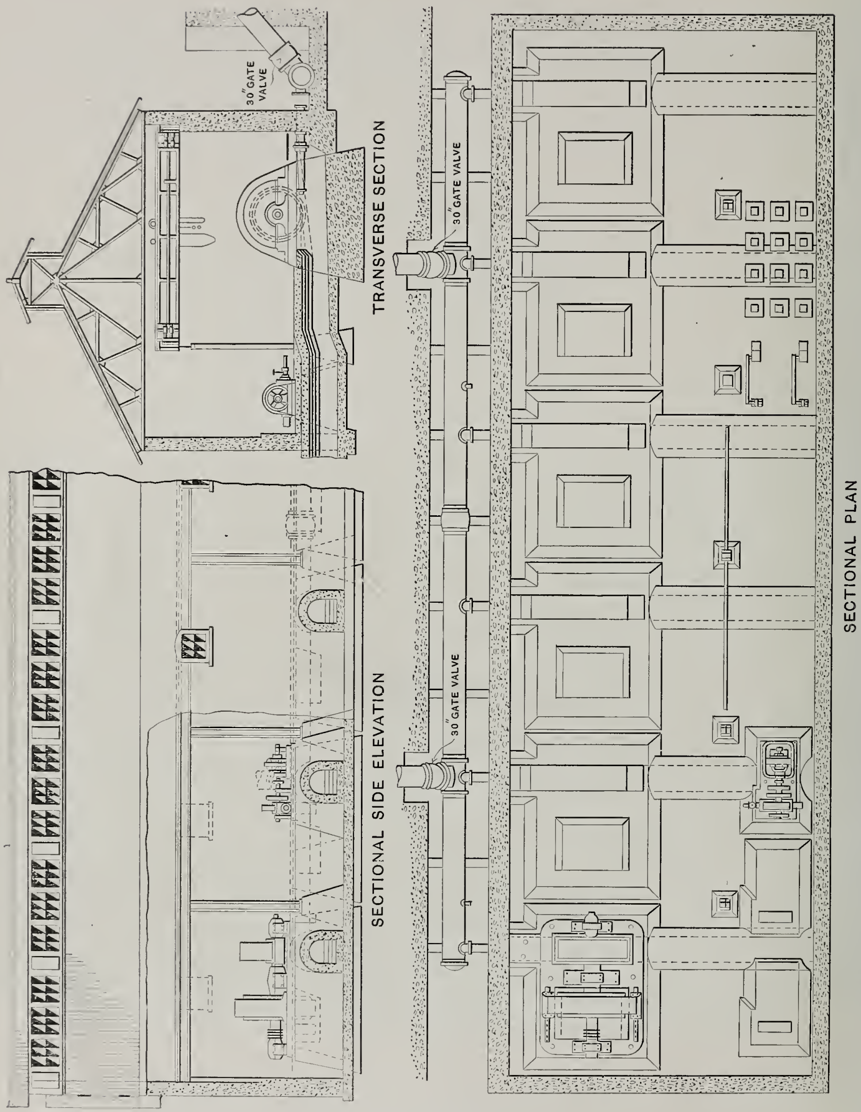
AN 83-MILE ELECTRIC POWER TRANSMISSION PLANT

By James A. Lighthipe

A BIT OF THE FLUME LINE

SOUTHERN CALIFORNIA can justly claim to be the pioneer of commercial long-distance transmission of electric light and power. In 1892 the San Antonio Light and Power Company built the twenty mile, single-phase, 10,000-volt transmission line to light the towns of Pomona and San Bernardino, and a year later the Redlands Light and Power Company installed one of the first three-phase plants in the United States. This was originally built as an eight-mile transmission at 2500 volts. Later on, by the use of step-up transformers to 10,000 volts, the lines were extended to Highlands, Colton and Riverside,—altogether a distance of about twenty miles.



PLAN OF THE POWER HOUSE OF THE SOUTHERN CALIFORNIA POWER COMPANY, SANTA ANA CAÑON

To-day, however, the most notable transmission plant in existence is that of the Southern California Power Company, designed to carry 10,000 horse-power at 33,000 volts over 83 miles of line from the power house to the town of Los Angeles. The Southern California power house is situated at the base of the San Bernardino Mountains, on the Santa Ana River, and the power water intake is at the junction of Bear Creek and the Santa Ana River, about seven miles below the famous Bear Creek dam. The water in this river, like all waters in Southern California, is owned by water companies, and as soon as it reaches the valley it is led off in irrigation ditches in different directions. Under these conditions, any power company using the water must not interrupt the flow, and the regulation of the Pelton water-wheels which are used must be by deflecting nozzles. The water is carried about two and a half miles, 80 per cent. of which is through tunnels, and the rest of the canal is open masonry and wooden flumes. The elevation at the intake is 3422 feet above sea level, and that of the power house, 2670 feet. The difference, less the grade of the canal, gives a static head of 735 feet on the wheel.

The arrangement of the power house is admirable and is a marked departure from that of other California companies using the impulse type of wheel. Each wheel is over its own tail race. A receiver runs the length of the building just outside the walls, and the piping for each wheel is flanged on to the receiver and enters the building separately. The water drops from each wheel into a separate tail race leading into a common basin outside of the building, which is used as a cushion for the water when it is deflected from the wheel. This arrangement enables one to get at any wheel at any time without interfering with the rest of the machinery. The only objection to this arrangement is the loss of head due to the water making two sharp right-angles.

The generators are of the rotating field type made by the General Electric Company, of New York. They are of 750 KW. capacity, three phase, and run at 300 revolutions. The revolving fields are excited by a 125-volt current brought to the generators through two contact rings on the shaft. As the amount of current used is small and the potential is only 125 volts, a nest of carbon brushes similar to those in use

THE POLE LINE TO LOS ANGELES

on railway motors is used. These require absolutely no care, and are seldom touched. Each generator is direct coupled to a Pelton water-wheel, the two being set on one bed plate, and thus making a very compact unit. The current from the generators is transformed from 750 volts to 19,000 volts by twelve 250-KW. transformers. These

ONE OF THE LOS ANGELES SUB-STATIONS. TWO UNITS, EACH CONSISTING OF ONE 2200-VOLT 3-PHASE, 300-KW. SYNCHRONOUS MOTOR DIRECT CONNECTED TO TWO 150 VOLT DIRECT CURRENT 150-KW. GENERATORS

INTERIOR OF THE SANTA ANA CAÑON POWER HOUSE. FOUR UNITS OF 1000 HORSE-POWER EACH. REVOLVING FIELD GENERATORS DIRECT CONNECTED TO PELTON WATER WHEELS UNDER 700 FEET, EFFECTIVE HEAD. INSTALLED BY THE GENERAL ELECTRIC COMPANY, NEW YORK

are connected in groups of three with the primaries connected delta and the secondaries "Y." This gives a potential of 33,000 volts between the main line wires.

The transformers are of the air blast type, and work with ⅜-ounce air pressure from an 80-inch blower, driven by a 3 H. P. induction motor. The transformers are set on I-beams over a concrete air duct, and are arranged with dampers so as to cut off the air from those not in use. There is a reserve blower with its corresponding motor ready to start up at a moment's notice, should it be necessary.

There are three 30-KW., four-pole exciters wound for 125 volts direct coupled to Pelton wheels, both wheel and exciter being mounted on a common bed plate. The piping for these wheels is independent in each case, and the small tail races are provided with a 10-inch iron pipe plugged at the end to take the thrust of the water from the nozzles when it is deflected from the wheel. The wiring from the generators and exciters runs to the switchboard through fibre conduit underneath the floor.

The low-potential switchboard is built of marble, and the switches are double-throw with two sets of main bus bars. This enables the operator to divide the generators and transformers into two separate and distinct systems. Any generator or any set of transformers can be thrown from one system to the other, or they can all be run together.

The high-potential panels are set on a balcony above the low-potential board, and are also of marble, and have heavy marble barriers between the switches. There are four panels for the primary side of the transformers, one for each set of three transformers. There are two panels for the main line, with an ammeter on each wire and a panel for throwing the lines in multiple. The two main lines leave the building, pass-

THE WATER INTAKE AT THE HEAD WORKS

HIGH AND LOW-TENSION SWITCH BOARDS,—750 AND 33,000 VOLTS

ing through six large terra-cotta pipes set in the wall at the end of the power house. Down the side of this wall are the lightning arresters, one for each wire.

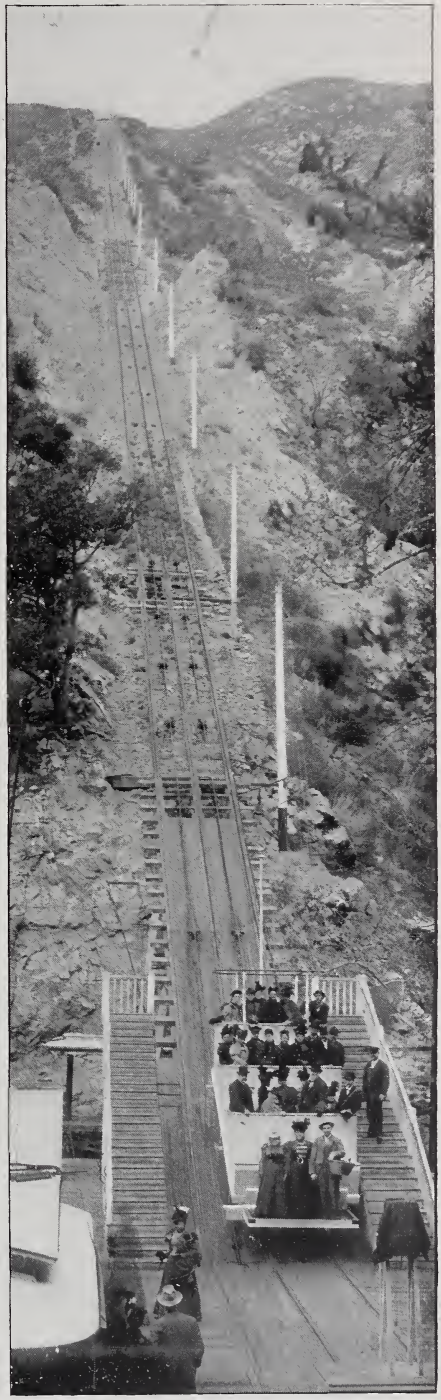
The Pelton wheels on the large generators are regulated by Lombard governors, using a head of two or three hundred feet for their hydraulic pistons. The water is drawn from the main pipe line into a small settling tank, situated a short distance up the pipe line. The wheels for the exciters are provided with small mechanical Replogle governors.

The transmission line from the power house to the sub-station in Los Angeles is about 83 miles long, and is composed of two circuits of three wires each of No. 1 Brown & Sharpe (No. 2 Birmingham) gauge copper wire. This wire was drawn half hard as an extra precaution against breaking. In the Santa Ana Cañon the poles are 30 feet high and 110 feet apart. There are about five miles and a half of this rough country. Then the line runs out in the open valley about three miles to Crafton. From Crafton to Los Angeles the line is on the Southern Pacific Railroad Company's right of way, and the poles are spaced about 120 feet apart. On this part of the line they are 35 feet high, except through the towns, where

they measure 50 feet. The wire on the poles forms two irregular triangles of 28 inches on two sides and 17 inches on the other, the upper cross-arm having two insulators and the lower one four. The circuits are spiralled every eighty eight poles on the south side and every forty-one poles on the north side, the spiralling being so arranged that they never come on the same arm of the poles. The insulators were thoroughly tested with a special transformer by Mr. O. H. Ensign, the electrical engineer of the company, before they were put on the poles, and the thoroughness of the test is proven by the total absence of trouble with the insulators up to date.

A telephone line is placed on two ordinary bracket insulators about 5 feet below the cross-arm, and the line is transposed every five poles, making the telephone service perfect.

At the main station at Los Angeles the current at 30,000 volts is reduced to 2200 by three 250-KW. transformers similar to those used in the power house. There is installed in this station a 300-KW., three-phase Westinghouse synchronous motor, but at present this motor is belted to an engine to be used as a generator to help out the peak load. The motor is synchronised with the large generators at the power house and runs in multiple with them, the engine being made to take what load is necessary by throttling. There is also installed a General Electric 525-KW. synchronous motor direct coupled to a 500 KW. 550-volt, direct-current dynamo. This unit is also belted to a large jack shaft carrying the several arc machines, and the shaft is so arranged that, in case of emergency, all the spare steam engines can be belted to it. By this arrangement, the large motor supplies 550-volt direct-current for the motor service and runs the arc machines at night, and, in case of a breakdown, the reserve engine runs the motor as a generator supplying three-phase current and 550-volt direct-current. There is a feeder line from this power house to a second sub-station in the heart of the business district and



THE CABLE ROAD UP ECHO MOUNTAIN

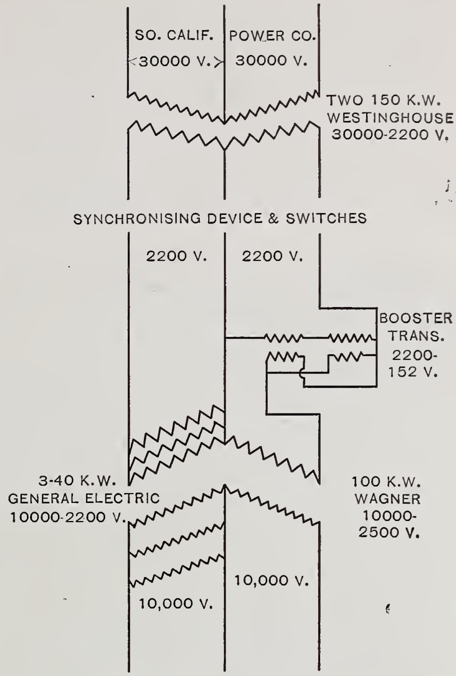
ONE OF THE WATER WHEELS AND GENERATORS, SHOWING ALSO THE WATER WHEEL GOVERNOR

THE TRANSFORMERS IN THE SANTA ANA CAÑON POWER HOUSE

and is the centre of distribution of the three-wire Edison system. This feeder is about 6000 feet long, half of which is overhead, and half of triplex-lead covered cable, drawn in underground conduits. At present there are installed in the second sub-station two units, each consisting of a 2200-volt, 300-KW. synchronous motor, direct coupled to two 150-KW., 140-volt, direct-current generators which feed the two sides of the Edison system. The mains of this system are the well-known Edison tubes. The lead-covered feeders are drawn through fibre conduit and connected with the junction boxes in brick manholes at the street corners.

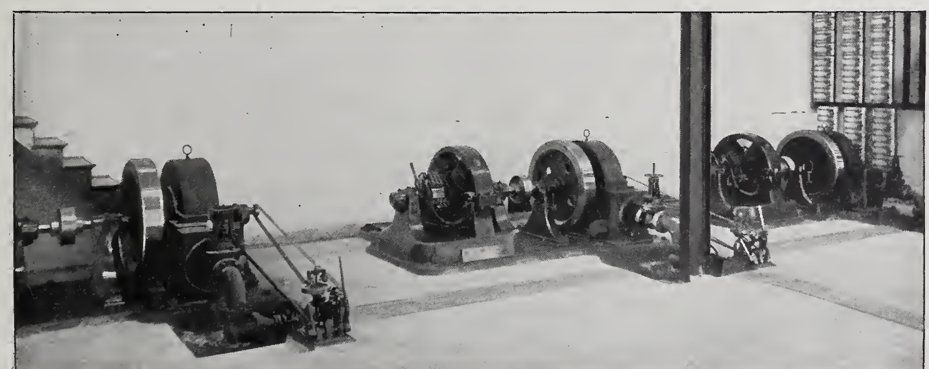
The three 250-KW. step-down transformers have not capacity to run the amount of machinery connected to them, but this will be increased in the near future.

At Shorb, about six miles from Los Angeles, a tap is made on the main lines and the lines are carried along the track of the Southern Pacific Railroad to Pasadena, the beautiful suburb of Los Angeles. There the current is reduced to 2200 volts by six 150-KW. transformers, and the single-phase circuits of the old lighting company are distributed on the three-phases. From this sub-station there runs a special feeder at 2200 volts to the summit of Echo Mountain, where it operates a 300-KW. rotary transformer, giving 500 volts direct current. This current is used to operate the famous Mt. Lowe Railroad, one of the



TEMPORARY METHOD OF TYING TOGETHER THE LINES OF THE SOUTHERN CALIFORNIA POWER COMPANY AND THE REDLANDS COMPANY

great attractions for the tourists that come every winter to Southern California. This road starts from Altadena, a suburb of Pasadena, and by an electric road of about 7 per cent. grade, twisting in and out of the cañon, reaches Rubio, situated at the foot of the steepest slope of Echo Mountain. Here the surface



EXCITERS DIRECT CONNECTED TO PELTON WHEELS

road is abandoned and a cable road, about 3600 feet long, run by a 500-volt stationary motor, runs to the top of Echo Mountain. From here, there are four miles of surface road to Alpine Tavern, at the foot of Mt. Lowe. This terminus has an elevation of 5000 feet above sea level, and the entire rise is made in about six miles. The scenery from this road is grand beyond description, and is a fitting finale for this remarkable transmission line, starting at an elevation of 2670 feet, where, in winter, the ground is covered with snow, then passing down the mountains and through miles of orange groves until within 250 feet of sea level, then again climbing to the snow-covered peak of Mt. Lowe.

ON THE ELECTRIC ROAD BETWEEN ECHO MOUNTAIN AND MT. LOWE

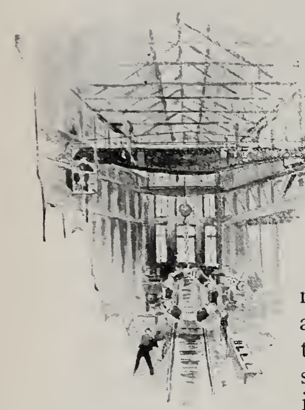
At Pomona, 33 miles west of Los Angeles, there are installed three 250-KW. General Electric air-blast transformers identical with those in the sub-station at Los Angeles. The current there is used for lighting the town and for pumping for irrigation. At Colton, 23 miles from the power house, the lines of the Southern California Power Company and the Redlands Electric Light and Power Company are temporarily tied together, the Southern California Company helping out the Redlands Company until the completion of their new power house, they having had no time to get standard apparatus for this work.

The lines were joined together in the following curious way, as shown in the sketch on page 11:—Two 150-kilowatt Westinghouse transformers, with a ratio of of 30,000 to 2200 volts, were placed on two sides of the triangle, and the current, after passing through the switches, meters and synchronising devices, was raised to 10,000 volts to match the Redlands circuit by placing three 40-KW. transformers in multiple on one side of the triangle and a 100-KW. transformer on the other side. The latter transformer being wound for 10,000 to 2500 volts, it was, necessary to boost up the secondary side to make the ratio the same as the other leg. This was done by two small transformers with the primaries in series and the secondaries in multiple. This arrangement has worked well ever since it was installed, and

the service has often called for very heavy overloads. As the operator at this point has no control over the speeds of either power house, it is necessary to wait for the lamps to show synchronism. As the speed of both power houses is run as near as possible to 50 cycles per second, they do not have to wait more than a few minutes to make the connection. This synchronising and tying together of lines twenty odd miles from either power house is a good example of the wonderful flexibility of the polyphase system. In starting this plant last February, the potential was raised very slowly,—a step at a time. At about 16,000 volts the lightning arresters started jumping, and it was necessary to increase the air gap in them about double. The brush discharge from the balls of the lightning arresters probably bridged over at least half of the air gaps. At about 18,000 volts the instruments at each end of the line gave indications that the current was jumping somewhere. Lowering the potential a few hundred volts stopped it, only to start again as soon as it was attempted to raise the potential. The plant was then shut down and a thorough inspection of the eighty-one miles of line was made without finding any trace of the trouble. The plant was then started at night, and the potential was raised to keep the current jumping, and the trouble was soon discovered. The line men, in running their wires, had crossed the line between two poles so that one wire hung about an inch below the other. This, from the ground, looked like a transposition, and so was not discovered. At about 18,000 volts the current would jump from one wire to the other, then run along the line, increasing its arc until it would break, then jump at the shortest distance again. The station agent at Ontario saw the fireworks two miles down the track and reported by telephone. As soon as the lines were cleared, the potential was run up to 33,000 volts with no more trouble. A great deal of credit for the successful operation of this plant is due to Edw. M. Boggs, the civil and hydraulic engineer, to O. H. Ensign, the electrical engineer, and H. C. Thaxter, superintendent of the Edison Electric Company, of Los Angeles; also to H. H. Sinclair for conception and organisation, to George H. Barker, president, and John B. Miller, treasurer, of the Edison Company, of Los Angeles, for their energy in pushing to completion, in the face of two of the driest years that California ever saw, the greatest feat of electric engineering to date.

SOME BRITISH OVERHEAD ELECTRIC TRAVELLING CRANES

By Arthur G. Parrott



THOUGH the obvious advantages of electricity as a means of transmitting power from a stationary generator to a locomotive machine have naturally exercised the minds of engineers, and have stimulated them to inventions of suitable devices for its application, it is only within a comparatively recent period that electric traction has been adopted in this country to any considerable extent.

As in road traction, so in crane driving, the almost insuperable difficulties that confronted the designer of a mechanical system was how to convey energy to a machine that was continually changing its position, even though locomotion was confined to a defined track. It is in this respect that electricity supersedes all other systems. The facility with which a machine can be continuously moved and yet be maintained in electric contact with a generating dynamo, together with the high efficiency, even when the current is transmitted over considerable distances, combines to make the system of electric operation superior to even the most perfect of all mechanical systems yet devised. Crane-makers soon realised the possibilities of electricity when applied to overhead travellers. Hitherto the majority of power cranes have been driven either by means of a high speed rope or by a specially arranged line of shafting running the full length of the crane-travel. In both these types a large proportion of the power applied to the cranes is absorbed in merely moving the rope or revolving the shaft, and this consumption of power is constant, whether the crane is working or not. It is found that ropes consume 5 H. P. per 100 feet, which means that in the average shop of about 250 feet in length, 12½ H. P. is continually wasted in work of mere transmission. In a shaft-driven crane, the waste may be assumed to be quite as much and even more where the cranes have to work in dusty places, like foundries, or where the conditions are not favourable.

The practical difficulties attendant upon the exterior system of "energising" the crane led to the introduction of the self-contained types, such as steam travellers and hand power platform travellers. Steam cranes labour under the disadvantage of being excessively heavy in consequence of the weight of the engine and boiler, and are directly opposed to that desideratum of all engineers, the concentration of generating units.

Hand power platform travellers, except for very occasional work, and then only with light loads, cannot be seriously entertained by those whose operations are at all extensive, and where the economy of time and labour is of any consideration.

Of electric cranes there are two types in the market, the one-motor and the three-motor variety. The former undoubtedly owes its existence to the desire of makers of rope cranes to produce electric travellers without altering their patterns or designs. The mere substitution of an electro-motor for the travelling rope can be looked upon only as a compromise which may be excusable

THE CRAB OF AN ELECTRIC THREE-MOTOR TRAVELLING CRANE. BUILT BY MESSRS. VAUGHAN & SON, LTD., MANCHESTER

A SMALL ELECTRIC CRANE IN THE SILVER MELTING HOUSE OF THE ROYAL BRITISH MINT. CAPACITY, 10 CWT. SPAN 24 FEET. BUILT BY MESSRS. JOSEPH ADAMSON & CO., HYDE, ENGLAND

in cases where it is desired to rapidly and cheaply adapt an existing mechanically-driven crane to the new conditions. The retention of the elaborate headstock with its open and crossed belts, the cross-shafts with their tumbler bearings and worms in cranes of this type very largely minimise the benefits of electric driving. Complicated gearing and other mechanical devices, rendered necessary where three motions (each immediately reversible and independently controllable) have to be actuated by a single pulley running in one direction only, at a constant speed, are bound to lead to considerable losses of power, and involve a continual expenditure for maintenance. This point will be more fully appreciated by reference to the illustrations on pages 15 and 17, showing a crab of a 20 ton, three-motor overhead electric traveller and a crab of a modern 12-ton shaft-driven crane. The reduction of gearing to a minimum is not one of the least advantages of the three-motor travellers.

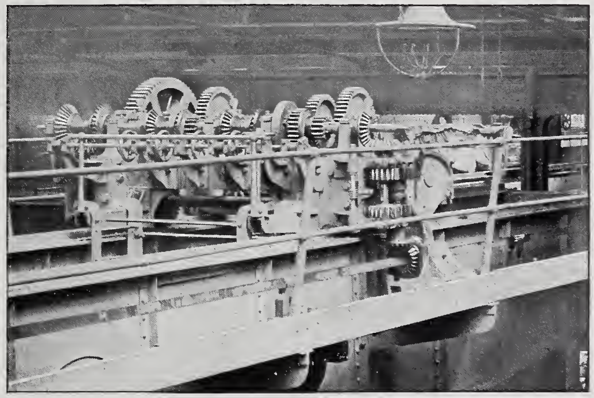
Engineers seem to generally favour direct current for shop work, although there seems to be an impression that when the Tesla patents have run out, polyphase driving will become predominant. The tax per installed H. P. seems to have been an effective bar to the general use of this form of current, and although there are several cranes at work for alternating current on the one-motor principle, crane makers seem unwilling to tender for three-motor polyphase current apparatus. Their reluctance arises probably from the fact that they can get, for the present, sufficient orders for direct-current machines. Want of experience in the control of the motors has, undoubtedly, something to do with their disinclination for polyphase current, although in view of the experience daily being gained in the use of continuous current, it is doubtful whether alternating current will rapidly come into general use, despite the advantages of commutatorless motors.

The disadvantages of series motors for regular service make them ideal for crane work. The high speeds of travel not possible by mechanical means are simply due to the variations

in speed of the motor in proportion to the load. Even in cranes with a longitudinal traverse of 400 feet per minute, the acceleration in speed is almost imperceptible, owing to the gradual working up of the travelling motor to its maximum number of revolutions as the inertia is overcome. The use of high speed motors for crane work cannot be recommended and in view of this fact every purchaser of electric cranes should make it a condition that the speed of the crab motors at least should not exceed 300 revolutions per minute. Though the use of such comparatively slow speeds necessitates more expensive motors, the advantages to be derived are considerable. Indeed, the longer life to the crane, the quicker stopping and reversing powers, and the smoother running of the gears more than compensate for the increased cost.

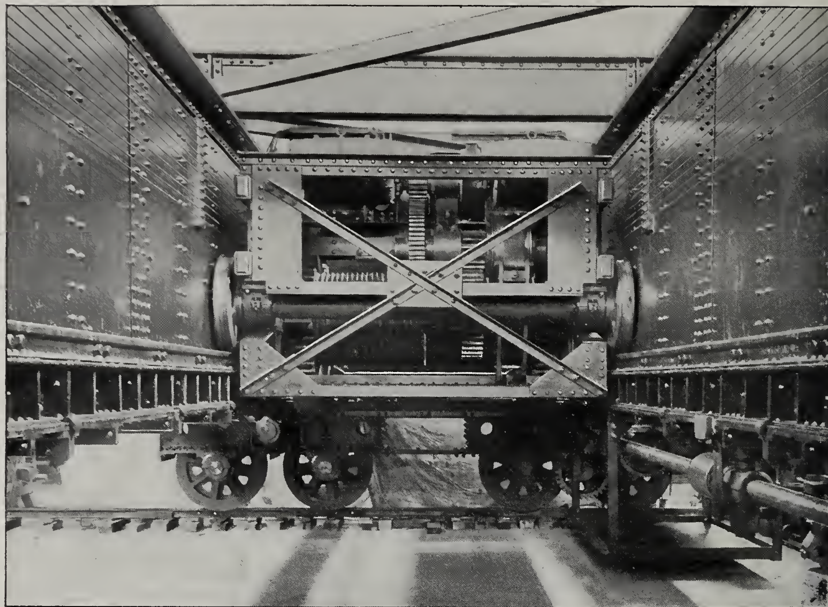
Owing to the fact that crane-motors are "intermittent workers," motor manufacturers have been in the habit of supplying machines too small for the work for which they are intended. They rely on the capacity of the machine for developing an additional 75 to 100 per cent. for short periods, and thus bringing the maximum horse-power up to what has been specified. The results in some instances have been curious, not to say disastrous. For instance, a crane maker might order a 10 H. P. for his hoisting motor, knowing that he has a right to expect that machine to develop 17 to 20 H. P., for short periods providing it is properly rated. But the motor maker supplies a 6 H. P. machine, doubtlessly appeasing his conscience by his knowledge of the fact that it will develop 10 H. P. intermittingly. The consequences are what might be expected,—injurious heating, excessive sparking at the commutator, frequently broken wires in the armature, and the total failure of the motor after a few months of unsatisfactory work. It is essential that crane motors should be most liberally rated, and in view of the comparatively slow speeds, all fields should be multipolar. Particular attention ought to be given to the size of the commutator, the area of brush contact, and the nature of armature windings.

The next important point in connection with three-motor electric cranes is the character of the switches. It is still an undecided question which is preferable, the metallic or the liquid resistance type. The frequent renewals consequent upon the sparking in connection with the metallic contacts,—even when the motor is specially wound to suit,—puts them at a disadvantage when compared with the liquid resistance type with which contact is made and broken on the surface of the liquid, thus obviating any sparking about the details. Still in the latter there remains the objection arising from the presence of the liquid, and the care required in keeping it to the right consistency. The price of car controllers with magnetic blow-outs or arc-dispersors puts them out of the question where first cost is of any consideration.



THE CRAB OF A MODERN SHAFT-DRIVEN CRANE

The principal makers in Great Britain seem to favour the liquid type of resistance with the reversing switch combined. The usual arrangement consists of a cast iron cistern or trough to contain the solution, generally caustic soda



INTERIOR OF BRIDGE OF A 150 TON ELECTRIC TRAVELLING CRANE

and water, carrying on its upper part the gear. The handle operates simultaneously a commutator of two sections, positive and negative, and the resistance plate which makes contact with the liquid.

Forward and backward movements of the handle alternate the sections of the commutator that are in contact with the two fixed collectors connected to the armature brushes, and so cause a reversal in the direction of rotation of the motor. The operation of reversing is accomplished before the resistance plate touches the surface of the liquid. It is customary to place the switches in a cage, slung from the wheel-boxes. In this case they ought to be so arranged that the operator can manipulate the three motions separately or simultaneously, as required.

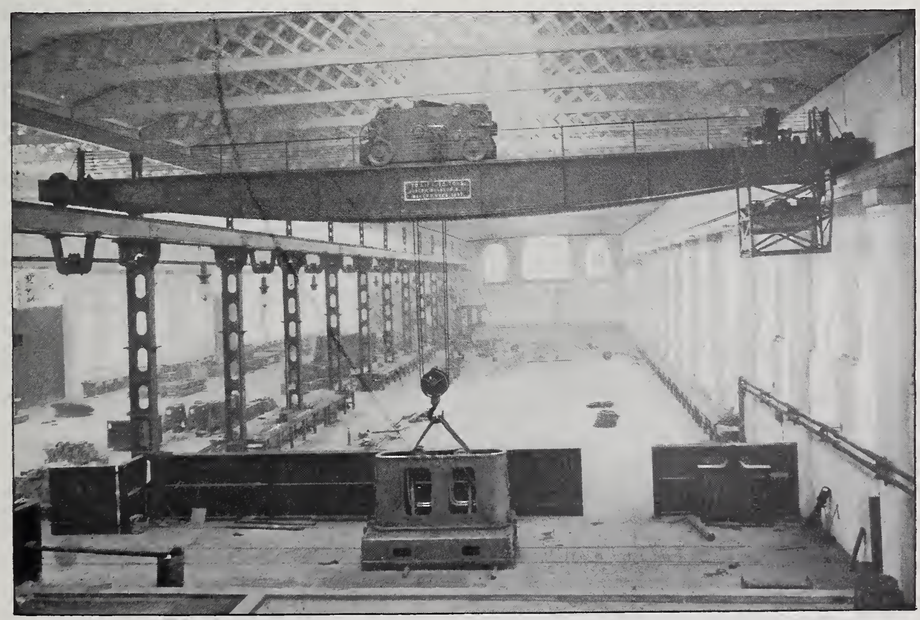
The equipment of the operator's cage, in addition to the three controlling switches, should consist of a seat for the attendant (which may also comprise a tool-box), an ammeter, and last, but not least, an emergency switch to cut the crane completely out. Fuse plates, with fuses so proportioned as to sever the circuit in the event of the current exceeding the safety limits, should be placed within easy access of the operator.

There are some special cases in which it is desirable to work the cranes from the floor level, but it is preferable for many reasons to appoint a special operator,—a boy will do,—and locate him in the cage. If the cranes are worked from the floor, it is necessary that the motions of the switches should be "fly back," so that as soon as the ropes or chains dependent from the switches (which are usually carried on the crane girders in such an arrangement) are released, current is cut off from the motors. The chains or cords are a source of continual danger from their liability to catch, and so start the motors, and the speed of longitudinal traverse must be reduced so that the crane does not travel faster than the operator, on foot, can cautiously proceed.

Local considerations govern the question of speeds to a certain extent; but, generally speaking, cranes up to 30 tons, with light loads, should have a longitudinal traverse of not less than 250 feet per minute and a cross traverse of about 150 feet per minute. To those

who are accustomed to the slow movements of rope or shaft-driven cranes, these speeds may seem dangerously high by comparison, but practical experience in the working of both types shows that the speeds crane makers have hitherto adopted as their standards for mechanically driven cranes have been absurdly low. Hoisting may be accomplished at more moderate speeds, and may be varied with the load. A series wound motor that would lift 30 tons at 3 feet per minute ought to lift in the quick gear a 5-ton load at about 18 feet per minute, which is quite quick enough for ordinary shop requirements.

Latterly the best makers of electric cranes have the motors so arranged that worms, worm wheels and bevel gears and their concomitant evils are entirely dispensed with. In the earlier types, the power from the hoisting motor was transmitted by means of a worm to the hoisting gear, the idea being to make the crane self-sustaining without the use of a brake. Experience has proved that this arrangement, where heavy work is concerned, is not reliable since in one instance a crane, constructed on this principle, allowed its load (a partly finished locomotive) to take charge of the motor and run down with a dangerously high velocity. Usually spur gearing is now used throughout in conjunction with an automatic magnetic brake. When current is switched on to the hoisting motor it puts into circuit an electro-magnet possessing sufficient power to raise the brake lever and render it inoperative at the moment that hoisting or lowering commences and also during its continuance. The act of "switching off" immediately, and without any attention whatever on the part of the operator, allows the brake to be automatically applied. It is necessary that the brake lever be fitted with a damping arrangement so as to prevent the excessive shock to the gearing that would otherwise arise in the event of the brake being too suddenly applied. The advantage of the magnetic brake is obvious. If from any reason during working operations, the current should fail, the brake lever would be instantly released, and the brake would take charge of, and sustain the load. Mechanical brakes of various



A 15-TON 47-FOOT SPAN ELECTRIC CRANE. BUILT BY MESSRS. JOSEPH ADAMSON & CO.

designs and principles are sometimes used in conjunction with the magnetic brake just described.

It has been found necessary with the introduction of the high speeds of crane-travel to increase the strength of the girders, which should be so proportioned that the maximum loads should not exceed one fifth of the ultimate strength of the material in the lower flanges. The top flange should also be so designed as to easily resist the lateral strains that occur by suddenly stopping and starting the crane when fully loaded. In one instance, where this oversetting tendency was not sufficiently provided for, the girders collapsed, and the whole structure fell to the floor with fatal results.

One of the leading American crane makers has adopted an unusual form of girder. It consists essentially of two plate girders of uniform depth connected together by cross and diagonal bracing on the top flanges and carrying on their contiguous faces near the lower flange the rails upon which the crab travels. An objection to this form of girder lies in the fact that the crab, being completely enclosed within the bridge, is consequently out of sight, which invariably is equivalent to being "out of mind." The difficulties attendant upon its inspection and repair must outbalance whatever advantage of increased lateral stiffness is claimed for it by its makers.

One of the strongest recommendations of electric cranes is their economy of power. It has been previously stated that the transmitting rope in a rope crane absorbs about 5 H. P. per 100 feet. Compare this with an electric crane where the generator is driven from the ordinary line shafting! Except when the crane is actually working, the belt is to all intents and purposes running on the "loose" pulley. Now even in the busiest shops cranes are seldom engaged more than 40 per cent. of the working hours; the remaining time is occupied in preparing loads, adjusting slings, etc. Of course, during this interval practically no power is required to drive the armature of the dynamo. How very different is the case of the rope or shaft-driven cranes, where the consumption of power is constant whether the crane is working or not.

The following conclusive figures are the results of a test made by the Electric Construction Company, Ltd., of Wolverhampton, on a 5-ton three-motor overhead electric traveller by Messrs. Vaughan & Son, Ltd., of West Gorton, Manchester.

5-TON OVERHEAD ELECTRIC TRAVELLER.

Motion.	Speed.	Amperes.	Volts.	H. P. absorbed.
Hoisting 5½ tons	5.5 ft. p. min.	28	100	3.87
light	11.5 " "	8	100	1.07
Cross traversing 5½ tons	85 " "	16	100	2.1
light	110 " "	6	100	.8
Longitudinal traversing 5½ tons	260 " "	38	103	5.2
light	300 " "	26	103	3.6

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THE SAFETY OF PETROLEUM FUEL

By James Holden, Locomotive Superintendent of the Great Eastern Railway

IN a paragraph which appeared in the issue Cassier's Magazine for April, 1899, a statement is made that there is a grave risk of danger and trouble when using petroleum as fuel from the "snapping out" or sudden extinction of the fire and its restarting. That some systems of burning oil with delicately adjusted apparatus may be liable to such defects, the present writer will not dispute, but from an experience extending over about twelve years he has not found such liability to mishap with the burners he has employed, and, further, he is satisfied that if only the most elementary precautions are taken in the storage and manipulation of the oil, there is no reason why it should not be one of the safest, if not the safest, of the heat-giving mediums.

As regards any liability of danger from the fuel itself, doubtless residues with a high flash point are to be preferred, not only on account of the safety with which they can be stored and handled without exceptional precautions, but also because, when being injected into the furnace, their high ignition temperature and dense specific gravity guarantee the whole being burnt without loss by vaporisation through being brought into contact with the hot steam used for spraying. When, however, it is necessary to employ lighter oils and products, some revision in the methods of storing, handling and burning will satisfactorily remove any risks.

Of the many products used as fuel, the tar which is a residue from the manufacture of oil gas from petroleum is perhaps one of the most troublesome with which the writer has had to deal. The flash point varies considerably, as it depends largely on the grade of oil used for the gas and the temperature of the retorts in which it is made. It is often as low as 70 degrees F., and to remove any risks which might accompany the employment of such material as fuel, it is desirable that it should be stored in underground tanks, away from the boilers fired, and the writer has accordingly arranged the burners to lift the fuel by suction from the tanks so placed. The tanks have suitable ventilating pipes to carry off any gas generated. All openings are provided with wire gauze strainers or sieves of such a mesh that flame cannot pass. At the filling manhole this gauze filters the fuel and removes all dirt and grit. Fig. 1 shows the general arrangement.

On locomotives such a method of storage as described is out of the question, and some other arrangement had to be devised when crude oil of low flash point was introduced as fuel on the railways of Southern California. The fuel tank there has been placed entirely within the water space of the tender, as shown in the outline sketch, Fig. 2. As a safeguard against oil escaping by any damage to the connecting pipes between

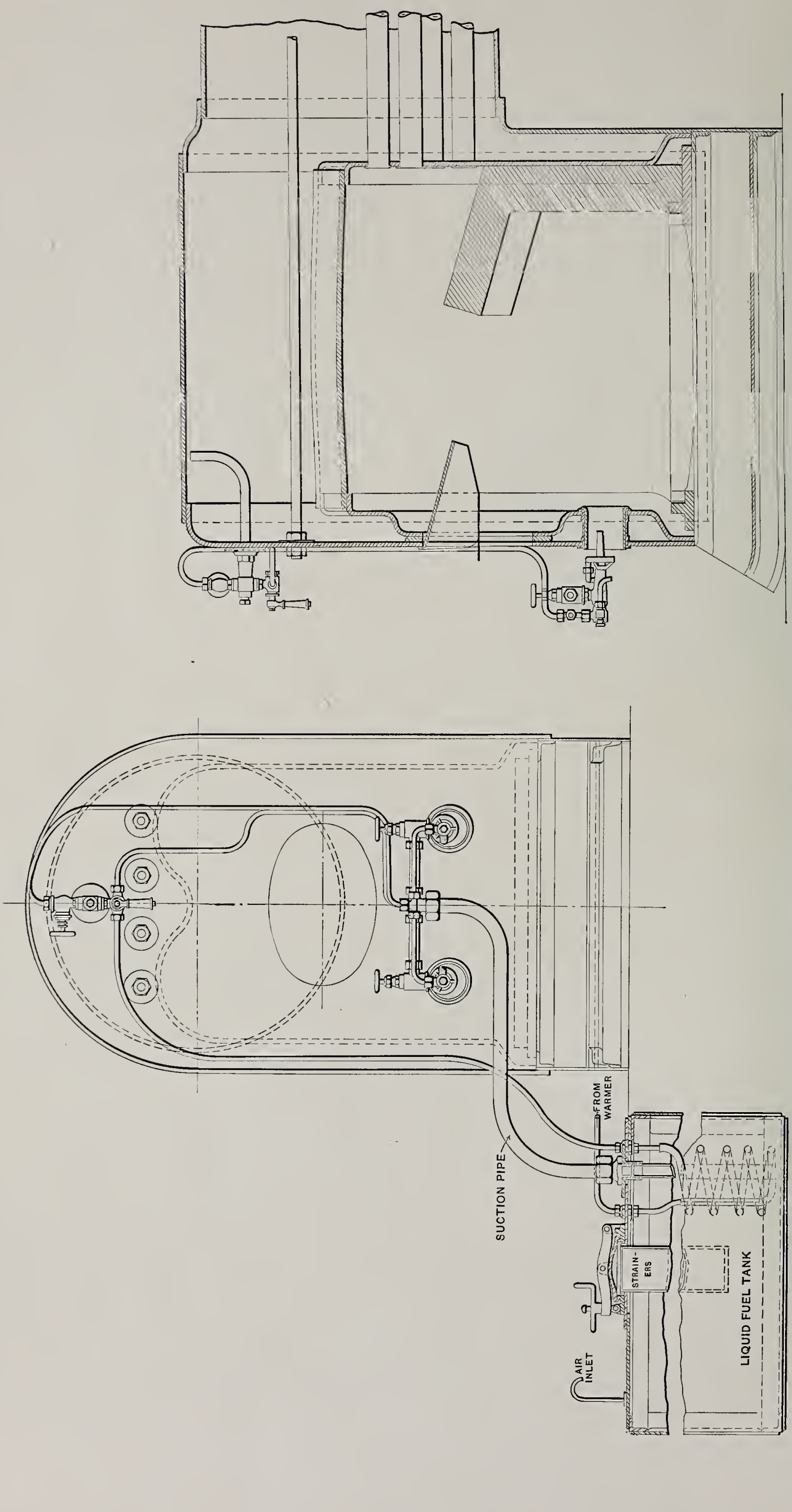


FIG. 1.—HOLDEN'S APPARATUS FOR BURNING LIQUID FUEL FITTED TO A STATIONARY BOILER

engine and tender, through derailments, for example, an internal valve is provided in the oil tank at the outlet; this is held open when in use by a small chain secured to a hook in the cab of the locomotive, and breakage of this chain ensures an instantaneous closing of the valve.

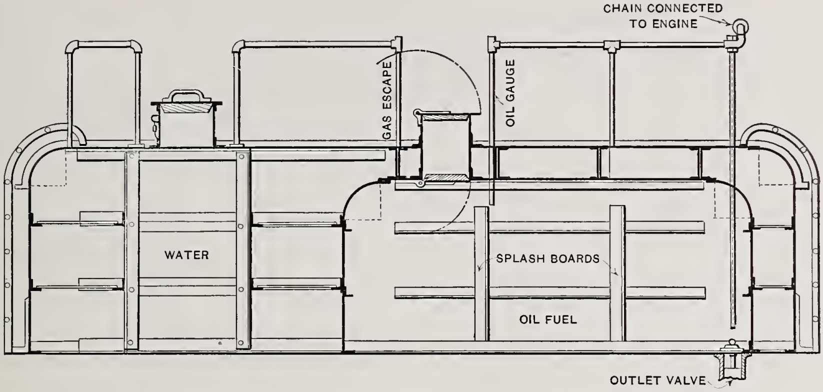


FIG. 2.—A COMBINED OIL AND WATER TANK FOR TENDERS ON THE SOUTHERN CALIFORNIA RAILROAD

In Great Britain, although dealing with fuels of a high flash point (250 to 300 degrees F.), it was deemed advisable in the early days of oil firing to provide strong cylindrical tanks on the tenders, with separate connections so arranged that in case of mishap they would leave the tender and fall clear. As, however, during the number of years oil-burning engines have been running no accidents have occurred, it is now the practice to have one single tank of larger capacity, made to drop into the water space of the tender.

Before leaving this branch of the subject, it should be pointed out that any serious mishap to the tanks, their connections or fittings, whether on board ship, attached to stationary plant, or on locomotives, means an interference with the oil fuel supply to the burners, and consequently an intsantaneous extinction of the fire.

Referring now to the suggested cause of danger set forth in the paragraph which has instigated this article, it is quite clear that should any foreign substance, dirt, grit or water, pass through the oil pipes and be delivered to the burners, a partial extinction of the fire may ensue, and then, if the obstruction is not quickly removed, the re-ignition of the oil is delayed by the cooling of the bricks, and gas is generated in the presence of a large quantity of air drawn into the furnace by the draught. An explosive mixture is thus formed, which requires only the presence of flame to lead to disastrous results. To prevent such a contingency arising, the oil fuel is passed through fine strainers, as already mentioned, having been previously allowed to stand for any water to separate out.

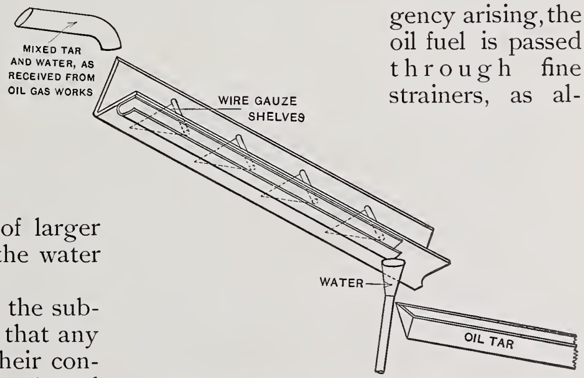
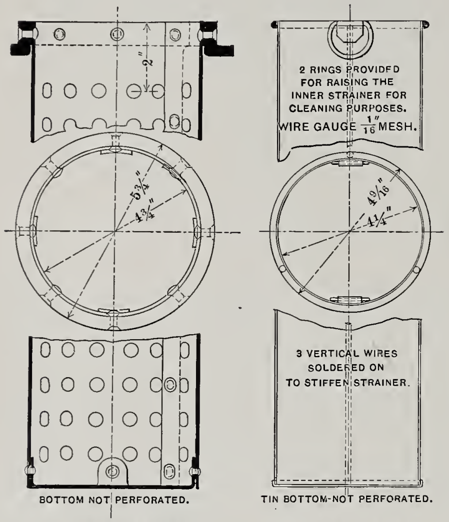


FIG. 3.—AN OIL AND WATER SEPARATOR

In cases where the specific gravity of the oil residue and water have been so nearly similar that there has been difficulty in separating them, two methods

of treatment have been adopted. The specific gravity of the oil has been increased by the addition of some heavier product, thus securing separation, or recourse is had to a mechanical arrangement which may be novel to some. It is shown in Fig. 3, and consists of a long wooden trough, placed at an incline, and provided with a number of ledges or shelves of perforated zinc or wire gauze at angles along its length; the



OUTER STRAINER INNER STRAINER

FIG. 4

mixture of oil and water is admitted to the top of the trough from the tank and in its passage down allows the oily portion to pass through the gauze ledges and along the bottom to the receiving tank. The water, on the other hand, forms globules, which run over the surface of the oily diaphragms and are guided by a little finishing ledge off each of the shelves into a second trough provided for their reception. With this rough apparatus, oil gas tar containing as much as 20 per cent. of water, entering at the top, has been collected at the bottom with only about 3 per cent. remaining.

Generally in Great Britain where tar or tar products have been employed as fuel, the water present has been allowed to collect on the surface of the storage tanks and then run over by filling up with heavy gravity mixture. With petroleum fuels, however, the procedure must be reversed, and on engines with tanks intended for this class of fuel suitable depressions should be provided for the water to be collected in and facilities given for drawing off at intervals.

To obviate stoppage of the burners by grit and dirt, the writer uniformly employs pipes of large dimensions with easy bends, straightway regulating valves, and burners with clear straight passages of reasonable dimensions. Further, he never places any strainers or such obstructions at any of the outlets or valves of the fuel tanks. All the oil is cleaned or filtered as it enters the tanks, not as it leaves them. Fig. 4 gives details of strainers employed at the manholes.

The " snapping out," as it is termed, can clearly be really dangerous only when it occurs on a large boiler or furnace with a large cubical capacity, and to further eliminate all risk from this, it has been the writer's practice, and that of his agents, in fitting the hundreds of installations at work, to so arrange the position of the burners that any explosion should be harmless. Figs. 5 and 6 represent a large furnace having six burners, and it will be seen that the area of the grate is divided by two walls of firebrick. In any of the portions, thus partitioned off, careless management would have no serious results.

It is in the lighting up of oil fires that care is desirable, and even then it is only necessary to introduce some waste or wood in flames before commencing to spray the oil fuel in order to ensure absolute freedom from risk of mishap. A little oil, allowed to run into the furnace over some lighted waste, will immediately provide a good flame, over which the fuel may be sprayed and ignited; but after allowing this portion of oil to enter the furnace it is always advisable to commence by admitting steam first and then gradually open the oil valves until the desired intensity of fire is obtained.

The complete substitution of oil fuel for coal on any boiler is a radical change

to make, and it would appear that a gradual transfer from one fuel to the other would be desirable; hence the provision in the writer's apparatus for the retention of the fire-grate available for coal whilst the oil fuel is being inaugurated. It has been found in practice that this is a good procedure, allowing the men to get accustomed to all the little peculiarities of the newer, cleaner and more efficient fuel.

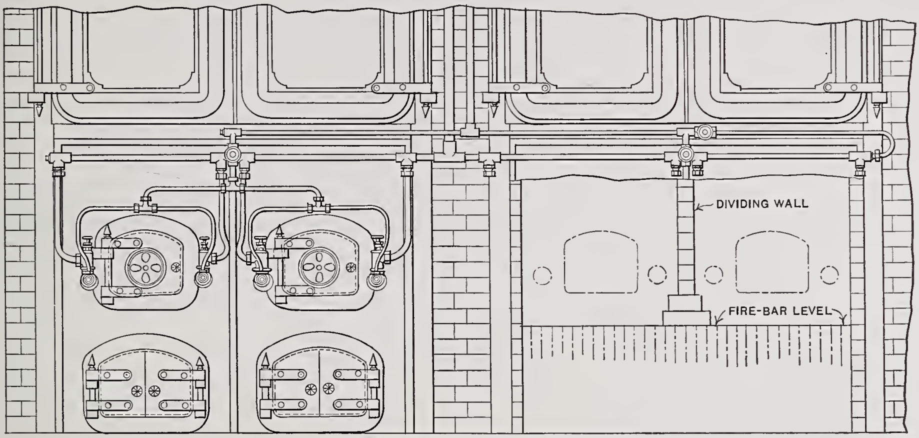


FIG. 5.—LIQUID FUEL BURNERS WITH SUBDIVIDED GRATES

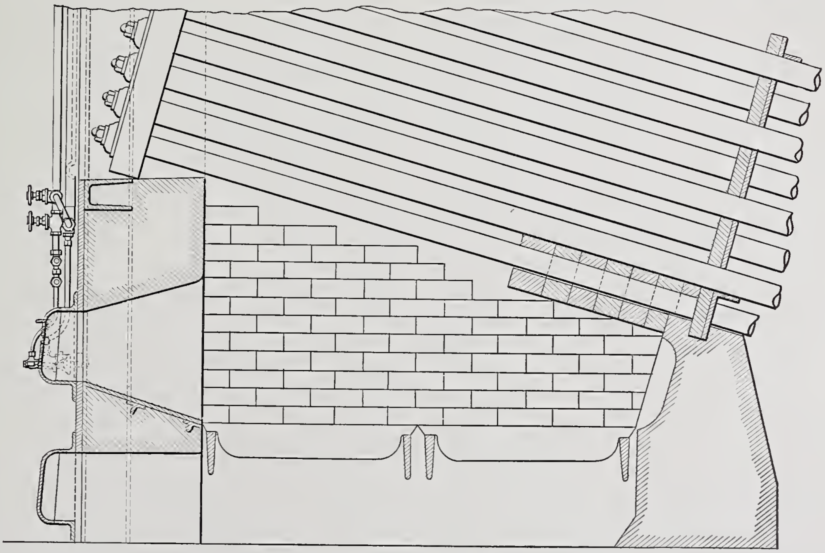


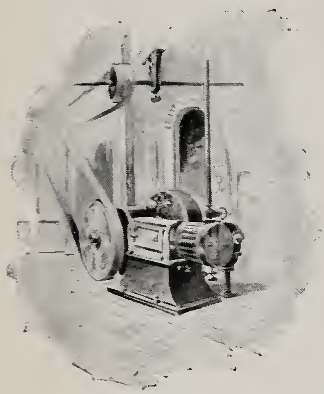
FIG. 6.—A SECTIONAL VIEW OF FIG. 5

On the Great Eastern Railway forty-seven locomotives have been in regular service for some years past on the main and suburban lines, hauling both passenger and goods trains, and not a single mishap has so far been recorded against their working with the oil fuel. Among the passenger trains, the fast special Cromer expresses should be mentioned; the long run of 130½ miles from London to North Walsham is made by these trains without stopping, maintaining a high rate of speed throughout the two hours and forty-two minutes occupied by the journey.

VALUATION OF MANUFACTURING PROPERTY FOR TAXATION

By Charles T. Main, M. Am. Soc. M. E.

In a paper recently read before the New England Cotton Manufacturers' Association Mr. Charles T. Main undertook to explain the reasons for the undoubted circumstance that in many instances the valuation of manufacturing plants is placed higher than it ought to be, and to set forth the methods used in determining the value in two cases which are now awaiting legal decision in the State of Massachusetts, U. S. A. The importance of the subject to manufacturers generally has prompted the reprinting of his remarks here practically in full.—THE EDITOR.



THE public statutes of Massachusetts state that the assessors shall make a fair cash valuation of all the estate, real and personal, subject to taxation. Strictly interpreted, cash value means market value, and market value has been defined as the sum which one party, who has the capital and who desires to purchase, would be willing to pay for a plant, the owner being willing, but not forced, to sell.

Into the market value of a plant enters the broad element of location, with its varying hours and price of labour; skill and abundance or scarcity of operatives; cost of transportation of raw material, supplies, and finished product; cost of fuel or power; cost of construction and equipment; and rate of taxation. Also the narrower and more restricted element of the physical condition of the plant and its relative value to a new plant constructed upon modern principles, and constructed with all regard to the economical production of a finished product of the best quality of the goods manufactured. The standard of value should be a modern mill, constructed as described above, and located so as to avail itself of as many combined advantages as possible. The ultimate value of a plant is its capability of producing a profit, and into the possibility of producing a profit enter all of the above items and perhaps some not mentioned.

It would seem that some of the items which enter into the market value must be ignored in determining the taxable value. The element of location and its effect upon the running expense must be eliminated from the problem, and the assumption made that the location is a favourable one for the transaction of business.

It is not at all improbable that some mills which are running at a loss, or making a slight profit, would be better off to abandon their present site and move their machinery to some more favourable location. It may have been that when such a ruling was made the choice of locations was not as wide as now, or that it was made to cover all property in a general way, much of which is not affected by these questions, and that it was intended not to consider such broad questions as must be considered by a purchaser, and which to him might render a property of no value, and yet it might represent a large amount of property.

It would seem, therefore, that in considering the taxable value of a mill, the assessors must ignore the broad questions of labour, location, transportation, etc., and confine themselves to the physical condition of the plant existing at a certain place, which place is assumed to be advantageous to the carrying on of the business. Assuming that this is correct, the problem is very much simpli-

fied, but is yet complex enough to suit any one, and can be viewed in different ways from different standpoints. This great difference comes in the manner of interpreting the words "physical condition," as to whether the interpretation stops in describing so much plant consisting of buildings and machinery and the condition of the same, or whether it not only describes the plant and its condition, but also the effect of its condition with regard to arrangement and character of buildings and machinery upon its earning capacity.

In each of the cases now pending, the representatives of the mills have maintained that the proper measure of value is a modern mill capable of producing the same product in quantity and quality as the present mill produces. The representatives of the cities have maintained that the measure of value is the cost of reproducing the existing mill at the time under consideration. If these two lines are followed out with an old mill the results will vary very widely, and the question to be decided is which one of these methods is the proper one for determining the taxable value. There can be no doubt that the former method, or that used by the mill, is the proper one to use to determine its selling value. It is the method which the prospective purchaser would use.

In determining the valuation, comparison is made with the cost of a new and model plant, and between the costs of operating the old and new plants in so far as the organisation of the old plant is detrimental to economical running, when such poor organisation cannot be rectified. When it can be changed to a proper organisation, the cost of making this change must be deducted from its value, if such defects did not exist.

The value does not necessarily depend upon the first cost of the property under consideration, which might have been excessive at the time of its inception; nor necessarily upon the first cost to-day of a plant identical with the one under consideration; for a smaller plant, owing to improvements, might be installed to-day which would produce the same results as the one under consideration. The first cost to be used in comparison, then, is the cost to-day of a plant which will produce equal results in quantity and quality as the one under consideration.

The value is determined by comparison with the cost to-day of a new structure with all the modern and improved ideas with regard to style of construction, large amount of window area, arrangement and size of rooms and buildings with reference to convenience and cost of operation and space occupied.

A mill or building with the old style of joisted construction, with low stories and small windows, and with a large number of small rooms, even if new, would not have the value of a modern mill building, with higher stories, large percentage of window area, and large, clear floor areas. To get the value of a building, the cost of a new and modern building should be depreciated.

First. For the difference in style of construction.

Second. For lack of light which makes it necessary to produce more artificial light.

Third. For the amount of floor space which is unavailable, due to the subdivision of the space or to the style of construction.

Fourth. For the increased cost of operation due to inconvenience of arrangement of rooms or buildings.

Fifth. For the increase in cost of insurance over that on a modern mill.

The amount of this depreciation for the difference in style of construction varies, decreasing as the building approaches in strength, form and convenience that of a modern structure. The depreciation for lack of light can be determined if it is known how much more artificial light must be burned, and the extra expense of the same, and capitalising this at the proper rate of interest. The depreciation for inconvenience and extra cost of running could be determined if the extra cost of running is capitalised at the proper rate. The depreciation for unavailable floor space is just the percentage which cannot be used. The depreciation on account of

higher insurance rates can be estimated by ascertaining at what rate the factory insurance companies would take the risk with buildings constructed according to their ideas, and to find the difference between the cost of insurance on the old plant and the new one. This difference would represent interest on the sum which one could afford to lay out on new buildings, or the sum which the old buildings should be depreciated on this account.

The proper rate at which to capitalise these amounts would vary according to the idea which a person might have as to a satisfactory return for the money expended. This was very much discussed in the two cases mentioned. The amount used by the witnesses for the mill was 10 per cent. on the assumption that any one would be willing to make an expenditure towards new buildings which promised an immediate return of 10 per cent. on the investment, but would not be willing to invest in property of this sort, whose value rapidly diminished and the relative return in comparison with that from newer structures would soon fall off. It was claimed by the counsel for the cities on the other hand that 5 per cent. was a proper rate to use.

It might be possible by certain changes to make the buildings as light and convenient as modern buildings, and, if new, they would be equal to the cost of such modern buildings, minus the cost of making the changes.

After determining the value of the buildings, if they were new, according to the above method, there remains to be applied the depreciation from age. This, to a certain extent, must be an arbitrary quantity, but based upon the average life of buildings of the character of those under consideration. It would seem that 1 per cent. a year is little enough for brick buildings substantially built, credit being given for any extraordinary repairs, renewals, or additions.

We must not lose sight of the fact that, although a building may not at the end of 100 years be completely worn out, the character of the business may so change that the buildings are not adapted to it, and that they will be rebuilt, as we have seen the older buildings replaced with new ones of different styles.

The depreciation of wooden buildings is greater than brick, depending upon the purpose for which they are used. Buildings which are kept dry, and not subject to much wear and tear, would, if well built, last a hundred years; while wooden dye-houses, subjected to steam and wet, will not last over, say, twenty-five years. The length of life depends largely upon the care which has been given to repairs. If the roof is kept in good condition and woodwork well painted, the depreciation is less than if no care is taken. If any marked renewals have been made, credit should be given for them. A whole new floor or roof may have replaced an old one, thus making that portion practically as good as new.

The first cost of a modern mill is the measure of value for the building under consideration, and not the first cost of this particular building; for the building may have been built in a very expensive way, highly ornamental, or in a location which caused very expensive foundations. None of these extra costs add anything to the productive value of the plant, and therefore must be sunk out of sight.

The two most important things which determine the market value of machinery are:—

First. Its comparative ability to turn out a product in quantity and quality equal to that of the most improved machines.

Second. Its actual condition with respect to wear and tear.

Although a machine may not be worn out, or even may have been run but very little, it may be unprofitable to run, because other machines have been introduced which do so much more or much better work. These machines may be used to advantage in some other concern, and may, on this account, have more value than scrap. Parts of machines have been improved so that these portions may be changed while leaving a portion of the machine as before.

The depreciation for actual wear and tear will vary with the severity of the work done, speed of the moving parts, the care taken in the running, and the amount laid out in repairs. It seems to me impossible to separate the depreciation from wear and tear altogether from that due to improvements in arriving at its present value, and it is customary to treat them in a general way, allowing a definite depreciation to cover both.

Any concern which does not lay aside, at least, 5 per cent. of the total value of its plant, if new, and apply the same at intervals towards renewal and improvements, will find itself at the end of twenty years in a position not able to compete with success with modern equipped concerns, and it will be necessary to make radical changes at great expense, calling for new capital.

It is often stated that there is no depreciation during the first year of running; that the machinery will do better work after it is limbered up and adjusted than when it is set to work. As a matter of fact, depreciation does begin immediately, although it may not be perceptible. After the first year, depreciation is charged sometimes at a uniform rate of 5 per cent. over all the machinery, due allowance being made for any renewal of parts outside of ordinary repairs. It is sometimes the case that some of the machines are older than these rates would allow to be in existence, but they may be still there, perhaps for the same reason that the bridge remained which the engineer had figured could not hold up its load. When asked how he explained the fact that it did stand up, he said that the only reason that he could give was that it stood from force of habit. Some machines remain and do work long after it would be profitable to replace them. The value of such machinery to a purchaser is practically nothing, except that it may complete the organisation of the mill and allow it to run until it can be replaced by new machinery.

If a sinking fund is created for replacing the machinery, 3 per cent. of the cost would replace it in twenty-four years. There is usually some value to machinery in a mill, even if the property were to be dismantled; but old machinery has no value except for scrap, which is very small, as the cost of taking down is about as much as the value of the scrap.

In an ordinary white mill it is known approximately how much shafting, belting and piping should amount to if new. It is possible that more than is actually needed to do the work has been installed, and although the cost may have been more, the value would be no greater than if the proper amount required for a modern mill had been installed. In fact, it may be a detriment to the mill to have more shafting and belting than is required to transmit the power in a well-designed mill, inasmuch as more power is required to drive the mill than would be required with a more simple arrangement.

In a mill which is not a plain mill, the safest way is to make a schedule of all shafting, belting and piping, and to make an examination to see if they are of the proper size and strength, or if they will require replacing, and to see if the bearings for shafting are such as to produce a minimum of friction and maximum economy of oil, and to see if it is worn. With belting, if a mill has been running for some time, it is customary to place its value at one-half the cost, if new, for the machine belts are being renewed occasionally. With piping the examination should be made to see if the steam pipes are proper for the most economical method of heating, or if they would have to be replaced, and if the pipes for hydrants and sprinklers themselves are such as would be approved by the factory insurance companies, or would have to be replaced, and to see what the condition of the pipe is. It should also be noted if the steam pipes are properly covered to prevent radiation.

It is also known about how much is required to equip a new mill with supplies, but probably the safest way to put a valuation upon these is to make a schedule and note the general condition.

It is customary to call the value of supplies one-half their cost new, as they are constantly being renewed, and that is probably as good an average value as could be given for a mill which had run for some years.

In most cases it would not be necessary to schedule shafting, belting, piping and supplies, but it would be near enough, and within the limits of error on the larger items of value, to treat them in a general way.

The value of the land where restrictions are placed upon it in connection with water power is a nominal sum, and the burden of taxes might be great if the values were placed as high as adjacent land used for other purposes and unrestricted. It is of no more value for manufacturing purposes than a lot in an open field, instead of being located perhaps in the congested portion of a city. The valuation should be moderate in order not to make the tax too great in proportion to the purpose to which it is put.

The taxable value of a water power privilege should be ascertained in comparison with the cost of steam power produced by the most economical method at any convenient location where coal is cheap, or by comparison with the cost of other water power favourably located. Unless this is done false values will be obtained. If the value of the water power varied directly as the cost of fuel, then the farther from a railroad the power is located, and the more it costs to haul coal to it, the more valuable would be the power. If raw material is to be brought to the mill and finished product to be taken away, it is a self-evident fact that the nearer to the railroad or seaport the mill can be located the more valuable will be the power which drives it.

SUMMARY OF METHODS USED BY MILL

1st. Determine amount of machinery required to produce the same results as the mill under consideration.

2d. Determine floor space required for this machinery if arranged in rooms of proper size.

3d. Determine savings which could be made by having well-arranged buildings and rooms.

4th. Capitalise this saving at 10 per cent. and deduct same from cost of buildings of modern mill. The result is the value of present buildings, if new.

5th. Depreciate buildings still further if necessary for poor style of construction, bad light, etc.

6th. Depreciate still further for age. This final result is the present value of the existing buildings.

7th. Determine savings which could be made by having modern and well-proportioned machinery.

8th. Capitalise this saving at 10 per cent. and deduct the sum from the cost of proper amount of modern machinery to do same work as present machinery. This gives the value of present machinery, if new.

9th. Depreciate this value, if new, for wear and tear, and this gives the value of the existing machinery.

10th. To the 6th and 9th results add the value of shafting, belting, piping and supplies, which are based on the cost of same for a modern mill, also the value of the land, water power, water power plant, and any other taxable property which the mill may own.

It appears that the chief criticisms which may be brought against the methods are as follows:—

1st. That the witnesses do not know whether any or all of the present machinery is working to its maximum capacity, and, therefore, do not know but what a greater product could be turned out with the existing machinery, and if the mill could be made to produce more, the size of the modern plant with which it is compared should be increased.

2d. That it may be possible to run the existing mill with a less number of hands, and that the saving with the modern mill is not as great as it would appear to be. The answer to this is that the effect of personal management must not enter into the problem, and that it is not a difficult matter to tell how much labour could be saved when running the present and modern mill

under the same kind of management, which is assumed to be good.

3d. The method of capitalisation is quite a bone of contention.

4th. The depreciation for age it is claimed should be made for only such depreciation as is visible.

The testimony for the defendant in one of the cases is not all in, and for the other case it has not been commenced. The writer is, therefore, anticipating some of the methods which will be used, and may be in error, but in general it will probably be as described below.

Determine the cost of reproducing the plant exactly as it stands on the date under consideration, and depreciate this for such wear and tear as is visible to get the present value.

An estimate is made of the cost of reproducing the buildings exactly as they exist. If they are small and narrow buildings with many rooms, where a few large rooms would be proper, the cost per square foot of floor space would be more than that for larger and wider mills; and the value of the old mills is represented as more than that of a modern mill. More square feet are required because of waste room caused by the subdivision, and the value is thus again represented as more than for a modern mill. Any especially expensive work which it has been necessary to do in the way of extra heavy foundations, piling, bad soil for excavation, etc., are clearly a part of the cost, but do not add anything to the value.

After determining the cost of replacing these buildings, which is called the first value, or value if new, depreciation is allowed for wear and tear, which is determined by an examination of the buildings and estimating what sum would be required to put them in as good condition as new, as far as such examination is able to reveal. This amount, deducted from the first cost, gives the present value. No depreciation is made for any other reason.

This method is improper because depreciation is going on which is invisible. An examination may show how much top floor must be relaid, but it does not show the condition of the planks or timbers. There may be no visible sign of depreciation of masonry, which, if properly built, will last a very long time, but not forever. There is no allowance made in this method for the advance in the art which in itself alone will in time require remodelling or rebuilding of the buildings.

An estimate is made of the present cost of installing machinery identical with that in the mill. This is called its value, if new. An examination is made of this machinery to see what its physical condition is, regardless of its age, and if frequent repairs have been made on it its value is said to be equal to new. Some slight depreciation may be allowed for wear and tear, and this depreciated value is called its present value.

No depreciation is made which is not visible, and no depreciation is made for the advance in the art. Depreciation does, in fact, begin immediately, and no one can escape the decrease in values due to improvements in machinery, which increase the product and decrease the cost of production.

A schedule of shafting, belting, piping and supplies is made and their first cost estimated, which is called the first value. This is depreciated for wear and tear. In an old mill poorly arranged and with more machinery than would be required in a modern mill, all of the above are in larger quantities than in the new mill, and apparently the value is greater. The fact is that, instead of being of greater value, they have less value for producing the same results, for the expense of running and maintenance is greater than with the smaller and less complicated plant.

The value of the land is determined by comparison with the value of adjacent land, or by sales of similar land oftentimes unrestricted and to be used in smaller lots for a different purpose.

The value of the water power is determined by estimating the cost of producing steam power at this particular location without reference to any other uses of steam. This yearly cost is capitalised at four or five per cent., and the sum is called the value per horsepower of the water power. This method

does not take into account the cost of producing water power, the cost of maintaining and running in nearly all cases of a supplementary steam plant, or the uses for exhaust steam. It assumes that the value of water power increases with the increase in cost of coal. The latter is true if the location is fixed, but it is not true, as stated before, that a remote water power is more valuable than one near a city because of the fact that it costs more to obtain coal at this remote place. There are other considerations which tend to reverse the proposition and make a water power of more value which is near a city than one which is remote. The method of capitalising at a low rate forever implies that the future relative cost of steam and water power will remain as at present, which does not seem to be at all probable.

SUMMARY OF METHODS USED BY CITY

1st. Determine cost of reproducing existing buildings exactly as they are constructed. This is the value, if new.

2d. Depreciate value, if new, by an estimated amount determined by an external examination of the various parts which can be seen. This gives the present value of buildings.

3d. Determine cost of replacing the machinery in the mill by similar machinery. This is the value, if new.

4th. Depreciate value, new, for wear and tear by an estimated amount determined by an examination of such parts as can be seen. This result gives the present value of the machinery.

5th. Make a schedule of shafting, belting, piping and supplies, and estimate cost of installing same.

6th. Depreciate first cost for any visible wear and tear to get present value.

7th. Estimate value of land from value of adjacent land.

8th. Estimate value of water power by capitalising yearly cost of steam power at a low rate of interest.

9th. Estimate cost of reproducing water power plant as it is, and depreciate for wear and tear, as above.

10th. To above present values add value of any other property belonging to mill.

It is substantially between these two methods that the court must now decide, and this decision, which is of much importance to manufacturers, is awaited with interest.

RECENT PRACTICE IN STEAM BOILERS IN GREAT BRITAIN

By W. D. Wansbrough

THE most notable event in the recent history of the steam boiler is undoubtedly the introduction, or rather, the reintroduction, of the water-tube system.

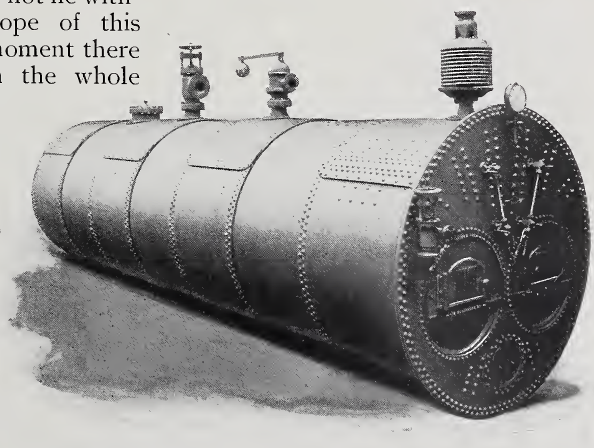
Fortunately, the question of its application to marine purposes does not lie within the scope of this article, for at the present moment there is, perhaps, no subject in the whole range of engineering upon which diametrically opposed opinions are so freely ventilated, by presumably competent authorities.

In the manufacturing industries, however, a calmer atmosphere prevails, and the water-tube boiler finds an acknowledged place in the list of available steam generators for certain services.

The boilers now in general use in Great Britain may be broadly classed into not more than five great divisions, if we exclude the vast tribe of small verticals and a certain class of externally fired boilers, which do not call for serious consideration outside the pages of the annual casualty reports of the insurance companies. These classes may be summarised as follows:

Lancashire: — All cylindrical, flued boilers, whether single, double or treble flued.

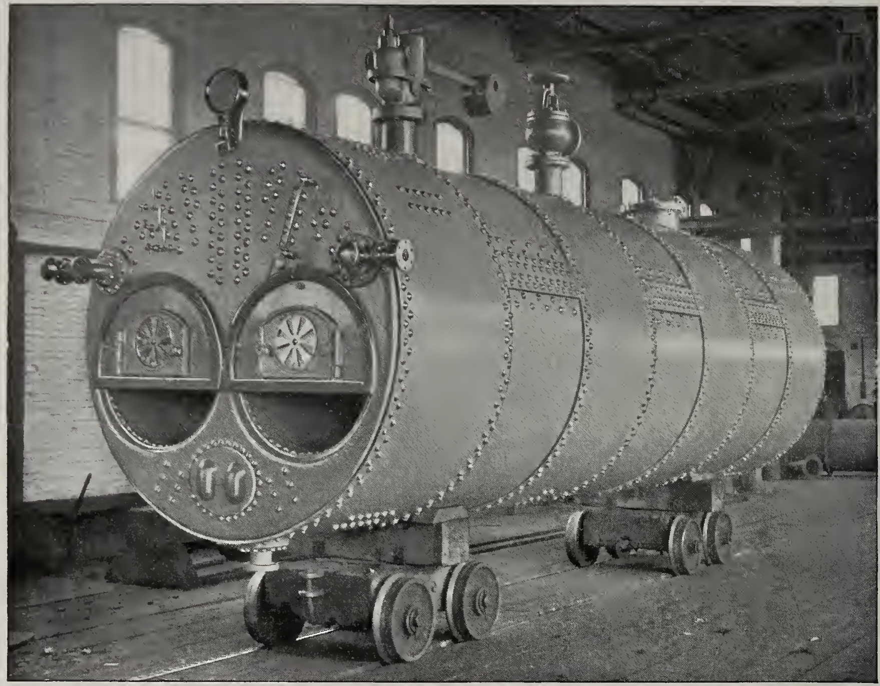
Locomotive type:—Rectangular firebox, with direct tubes.



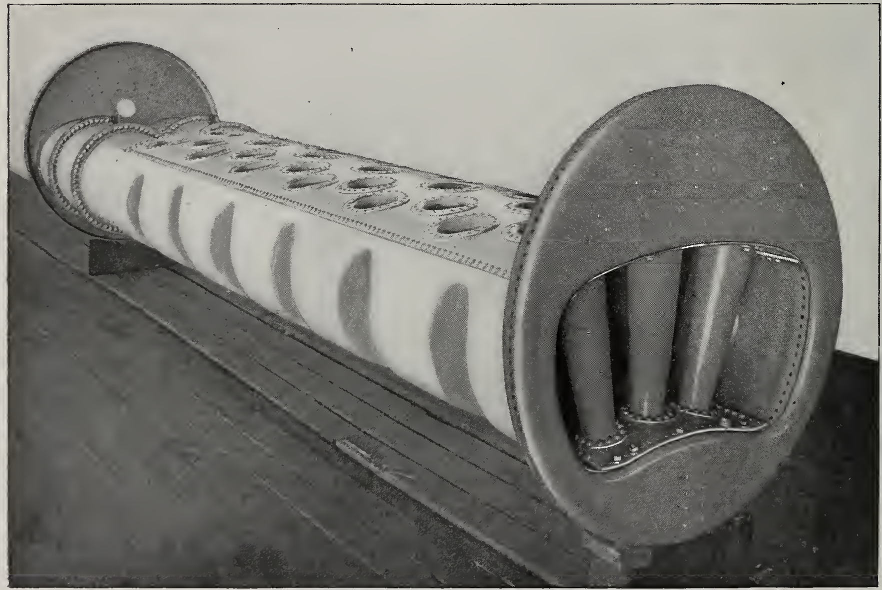
A LANCASHIRE BOILER. BUILT BY MESSRS. YATES & THOM, BLACKBURN

Marine type:—The Scotch, or cylindrical shell boiler with return tubes.

Multitubular:—Internally or exter-



A GALLOWAY BOILER. BUILT IN GREAT BRITAIN BY MESSRS. GALLOWAYS, LTD., MANCHESTER, AND IN THE UNITED STATES BY THE EDGEMOOR IRON CO., EDGEMOOR, DELAWARE



INTERNAL FLUE OF A GALLOWAY BOILER, SHOWING FLANGED HEADS, FURNACES, AND TUBES

nally fired cyndrical shell boiler with direct or return tubes.

Water-tube:—All boilers made up of elementary parts, or sections, exposed externally to heat or flame.

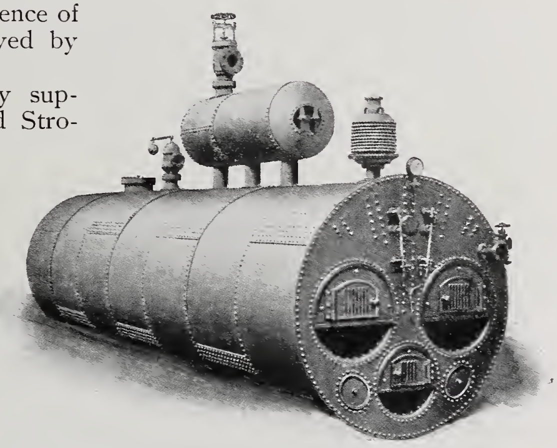
There being no compulsory inspection or registration of steam boilers in Great Britain, it is impossible to actually ascertain the relative distribution of these boilers throughout the United Kingdom. The returns of the boiler insurance companies, however, although these include only a small proportion of the total number of boilers at work, may probably, without serious error, be cited, for percentage purposes, as evidence of the degree of popularity enjoyed by each of the classes.

From information courteously supplied by Messrs. Crosland and Stromeyer, the chief engineers, respectively, of the Vulcan Boiler Insurance Company and the Manchester Steam Users' Association, the writer is able to give particulars of 36,426 boilers of the types enumerated, maintained under their supervision at this date. Now, although the clientele of these societies extends all over the kingdom, we may safely assume that the bulk of their connection lies in the great manufacturing districts of Lancashire and Yorkshire.

Here, then, we have important evidence as to the comparative frequency of the various types in the home of the engineering and textile industries. The incidental fact that the owners of these thirty-six thousand and odd boilers have placed them under the care of the societies, and have, in a large number of the cases, had the boilers constructed under their supervision, affords presumptive proof that some care has been exercised in the selection of the type employed in each case. The typical manufacturers' selection, then, comes out as follows:—

Lancashire	85¼	per cent.
Locomotive type	10	" "
Marine type	1¼	" "
Multitubular	1¾	" "
Water-tube	1¾	" "
Total	100	

Turning now to the returns, made up to the end of the year 1898, of the various electric light and power stations, municipal and private, in the United Kingdom, we find that, in the 179 provincial stations in operation and in progress at that date, the total number of boilers employed was 698. Now, the generation of electricity on a commercial scale is a new industry, and we may fairly assume that in each case the designer of the plant had a free hand in specifying the most serviceable and up-



A THREE-FLUED LANCASHIRE BOILER

to-date boilers within his experience. Here is the electricians' choice:—

Lancashire	53½	per cent.
Locomotive type	5	" "
Marine type	6½	" "
Multitubular	5	" "
Water-tube	30	" "
Total	100	

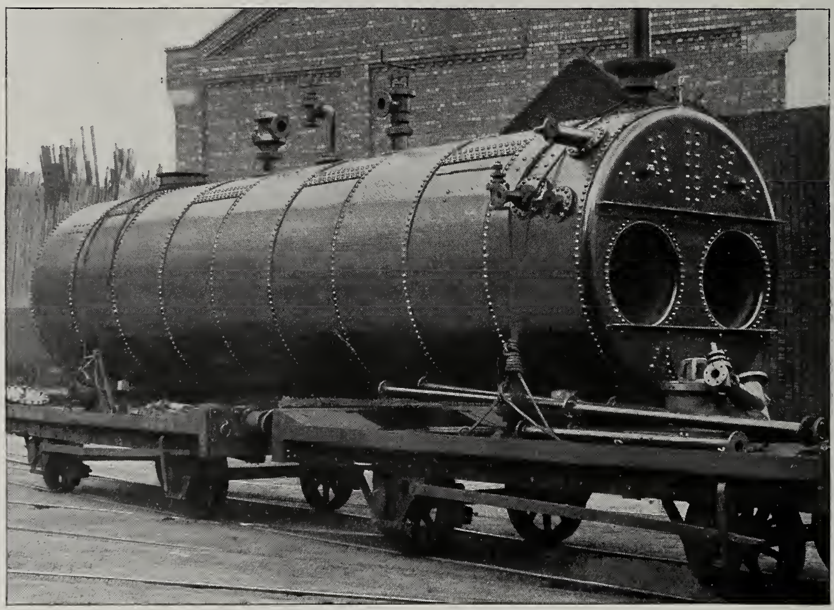
One example more! In the electric lighting and power stations of the metropolis space is golden. The cumbrous Lancashire boiler retires in favour of a more compact form of steam generator, and the water-tube type, occupying less than half the floor space, reigns without a serious rival. In London and district, out of a total number of 360 boilers in use, the returns show:—

Lancashire	11	per cent.
Locomotive type	4½	"
Marine type	4½	"
Multitubular	17½	"
Water-tube	62½	"
Total	100	

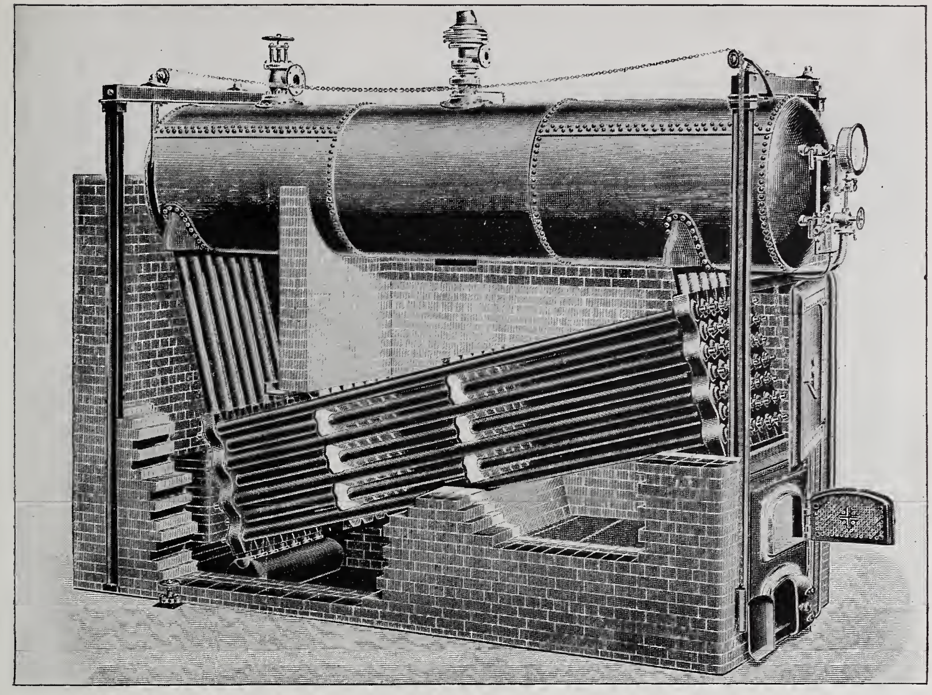
Having thus, to some extent, ascertained the relative values, numerically speaking, of the different systems in use for manufacturing and electrical purposes, we may briefly examine the claims of each type, illustrating, as we go, some recent examples by leading makers in each of the classes.

The Lancashire, or double-furnace boiler,—the standard stationary boiler in Great Britain,—is too well known to need description here. For nearly fifty years it has been manufactured with but little variation in its outward appearance. But the Lancashire boiler of 1899, as a piece of workmanship, is nearly as perfect as hands can make it; and, further, the construction, even down to minute details, has been so standardised that, practically, all first-class boilers of this type are now built not merely upon the same lines, but to an absolutely identical design. This remarkable unanimity has been mainly brought about by the influence of the various boiler insurance companies, chiefly located at Manchester, but in particular by the efforts of the Manchester Steam Users' Association, whose late chief engineer, Mr. Lavington E. Fletcher, made the improvement and development of the Lancashire boiler his chief aim, and by insisting upon rational design and first-rate workmanship, systematised the construction almost beyond the possibility of further improvement.

As a steam generator the Lancashire boiler stands pre-eminent (where the space at command will permit of its introduction) for several easily understood reasons. Its large water volume,—an 8 foot by 30 foot boiler contains nearly 20 tons of water,—converts it, once steam is raised, into a huge reservoir of heat energy. Hence sudden fluctuations in the demand for steam are easily met by its ample reserve, while inequalities in the firing are little felt for the same reason. Again, the evils of priming are practically unknown, owing to its large water surface, which is a powerful factor in the supply of dry steam. When fitted with the supplementary apparatus known as the economiser, the Lancashire boiler is a highly efficient and economical generator. Its heating surfaces, both internal and external, are completely accessible, and can be kept



A WOOD-BURNING LANCASHIRE BOILER. BUILT BY MESSRS. ROBEY & CO., LTD., LINCOLN



A BABCOCK & WILCOX BOILER. CONSTRUCTED ENTIRELY OF WROUGHT STEEL BY MESSRS. BABCOCK & WILCOX, LTD., RENFREW, SCOTLAND. BUILT IN THE UNITED STATES BY THE BABCOCK & WILCOX CO., NEW YORK

clean and free from deposits with the least possible trouble. Indeed, where the feed-water is exceptionally bad, the Lancashire, or its smaller relative, the Cornish boiler, is in some cases the only form which can be employed with safety. As regards strength, the Lancashire type of boiler can be, and is, constructed for pressures up to 250 pounds per square inch. Its circular shell, effectively, but not too closely, stayed ends, and comparatively small circular flues, strengthened at short intervals by reinforcing rings, adapt it for safely resisting the highest pressures.

Finally, we come to the important question of durability. Compared with some of the newer types of quick-steaming boilers, the Lancashire boiler is as the pyramids of Egypt to a suburban villa. At a recent discussion on water-tube boilers at the Institution of Civil Engineers Mr. Stromeyer, the chief engineer of the Manchester Steam Users' Association, stated that repairs to Lancashire boilers practically cost nothing, or on an average about sixpence per annum per boiler. This

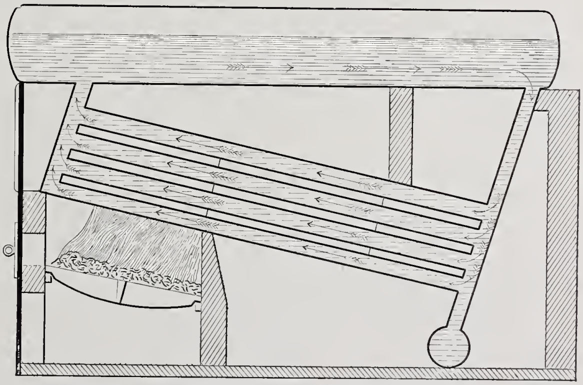
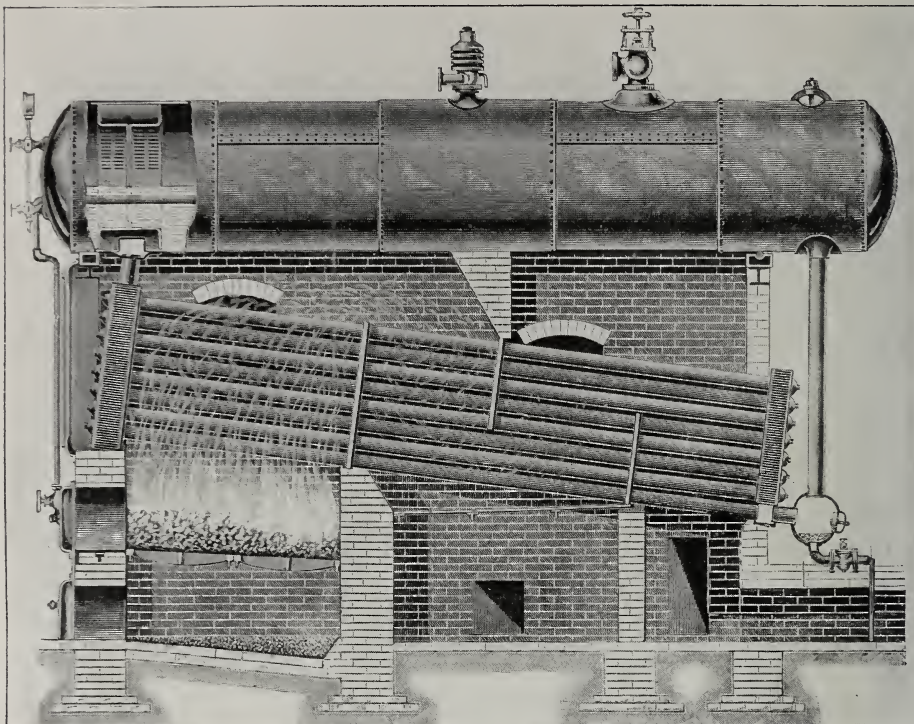


DIAGRAM SHOWING THE CIRCULATION IN THE BABCOCK & WILCOX AND THE HORNSBY BOILERS



THE HORNSBY WATER-TUBE BOILER. BUILT BY MESSRS. RICHARD HORNSBY & SONS, LTD., GRANTHAM

seems small, but, coming from such an authority, is a striking testimony to the lasting qualities of these boilers. The oldest Lancashire boiler on the books of his association is dated 1850; the oldest Cornish, 1845. Though most carefully watched, they show no signs of weakness after half a century's service.

The only important variant from the standard type of Lancashire boiler is the well-known Galloway boiler, in which the two furnaces unite in a common chamber, intersected by numerous conical cross-tubes, very clearly shown in the illustrations on page 34. The majority of standard Lancashire boilers are, however, fitted with these conical Galloway tubes in their circular flues, giving increased heating surface and improved circulation.

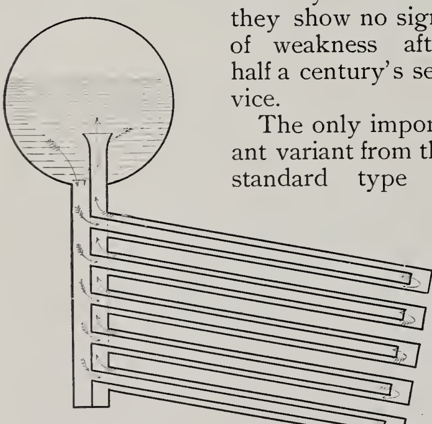


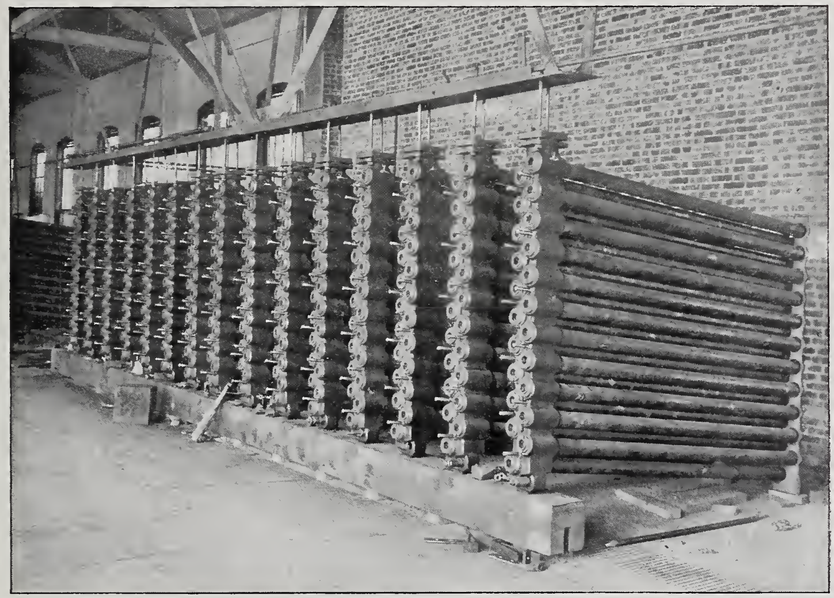
DIAGRAM SHOWING THE CIRCULATION IN THE NICLAUSSE BOILER

Messrs. Yates & Thom's three-flued Lancashire boiler, and Messrs Robey's Lancashire-type boiler for burning wood and refuse fuel, shown on pages 35 and 36, are also worthy of notice,—the latter being used in conjunction with an underground furnace-chamber of brickwork.

A more complete contrast in every way to the Lancashire type than its modern competitor,—the water-tube boiler,—it is impossible to imagine. Speaking generally, the latter embodies an inversion of all the characteristics we

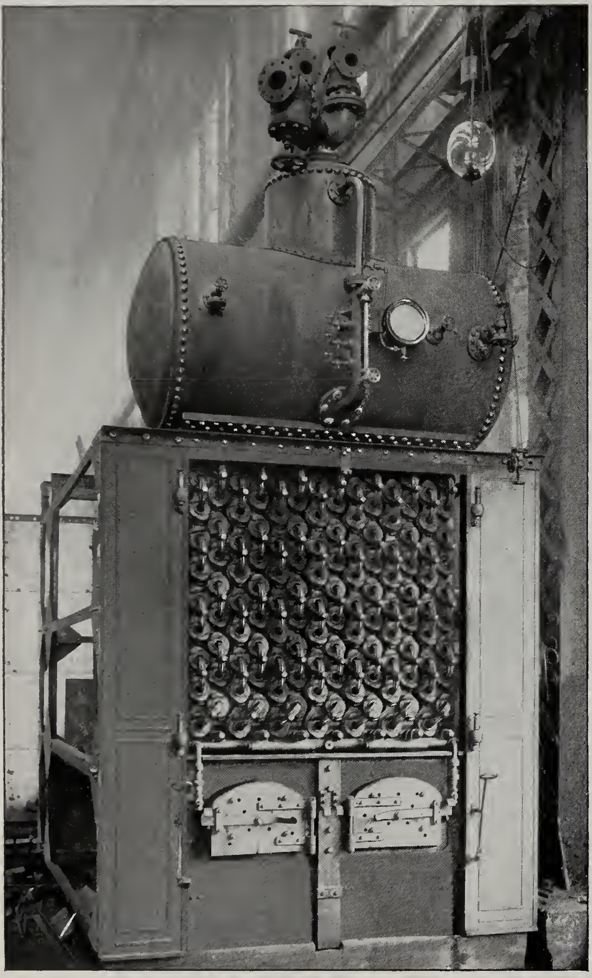
have been considering, and, purely for the sake of emphasising these differences, we will take it next in order. To analyse the details of construction in the numerous variations of this type would be impossible here; but in looking over the statistics of the electricity supply works in the United Kingdom, already quoted from, I observe that only three systems are specifically mentioned,—the Babcock & Wilcox, which figures most prominently in the returns; the Hornsby, and the Niclausse. These are accordingly illustrated as examples of the types especially favoured by that most progressive body,—the Metropolitan electrical engineers.

In the two first-named boilers, which possess many points of resemblance, the fire is made under the front and higher end of the tubes, and the products of combustion pass up between the tubes into a combustion chamber under the steam-and-water drum, being thence conducted, by baffle-walls of brick, twice or more times through the spaces between the tubes before escaping to the chimney. The water inside the tubes, as it is heated, tends to rise towards the higher end, and as it is converted into steam,—the mingled column of steam and water being of less specific gravity than the solid water at the back end of the boiler,—rises through the vertical passages into the drum above the tubes, where the steam separates from the water and the latter flows back to the rear and down again through the tubes in a continuous circulation. The steam is taken out at the top of the steam drum near the back end of the boiler after it has thoroughly separated from the water. A mud-drum, for collecting the impurities deposited from the water, is provided at the lowest point of the system immediately under the downtake pipes. In both these boilers the "headers," or boxes into which the tubes are fitted at each end, are of wrought steel; no cast iron is now employed. The tubes themselves are generally of wrought iron, lap-welded; in certain cases solid-drawn steel tubes are, however, employed. In the



SECTIONS OF THE NICLAUSSE BOILER. BUILT BY MESSRS. WILLANS & ROBINSON, LTD., RUGBY. THE BUILDERS IN THE UNITED STATES ARE THE WILLIAM CRAMP & SONS SHIP AND ENGINE BUILDING COMPANY, PHILADELPHIA

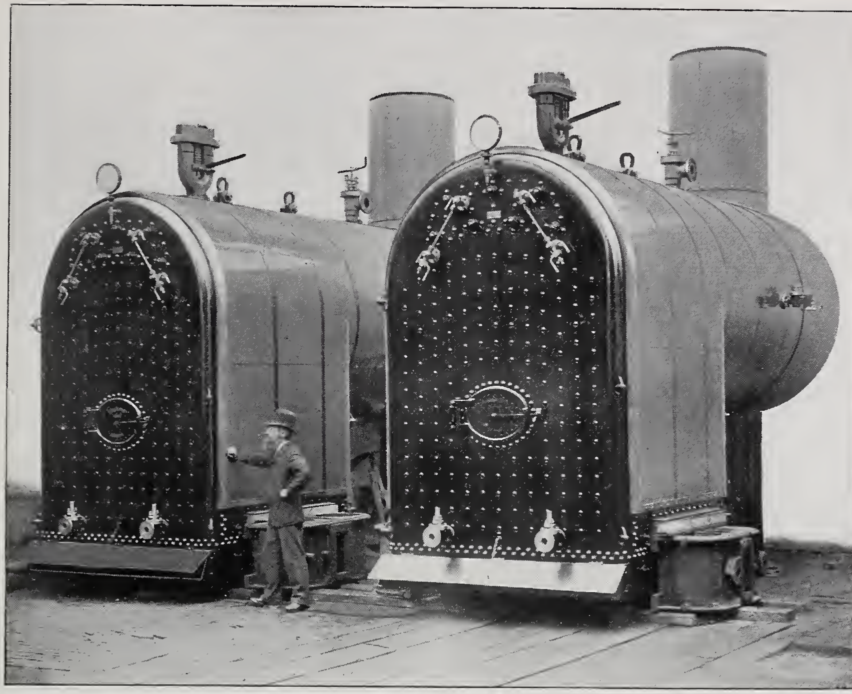
Niclausse boiler, the sole manufacture of which for the United Kingdom and the British colonies has been taken up by the well-known firm of Willans & Robinson, Ltd., Rugby, the back headers are dispensed with, the heating tubes being closed at the back or lower ends. The front headers are double, the front chamber of each communicating only with the inner or circulation tubes. Through these the downward current of water from the drum overhead flows, and is delivered at the further end of the generating tubes, the heated return current passing through the back compartment of the header into the drum again. The grate is of the same length as the tubes, and the products of combustion pass continuously upward towards the chimney, not being baffled, as in the longer boilers of Babcock & Wilcox, Hornsby and others. In this boiler access is not required to the sides or back, every part being easily got at from the front; one disadvantage of -this system is that apparently the boiler cannot be emptied or drained of water without some difficulty.



A FRONT VIEW OF A NICLAUSSE BOILER

The advantages of the water-tube boiler generally may be enumerated as follows:—The rapidity with which steam can be raised from cold water, say, in an hour or less after lighting up; the small floor space occupied, less than half that of a Lancashire boiler of equal power; immunity from disastrous explosion, being thus peculiarly adapted for very high pressures; their heating surfaces with ready transmission of heat; freedom for expansion, hence no strains except those actually due to the steam pressure; accessibility for cleaning the surfaces, both internal and external, of the tubes; damaged tubes easily removed and replaced, and sections easily conveyed through ordinary doorways or into difficult positions; excellent combustion, the currents of gases being broken up and thoroughly mixed by their passage amongst the groups of tubes.

But the water-tube boiler possesses the defects of its qualities. Its quick steam-raising powers are due, not to superior evaporative efficiency, but to the small quantity of water contained relatively to the extent of heating surface. Hence, the reserve of power be-



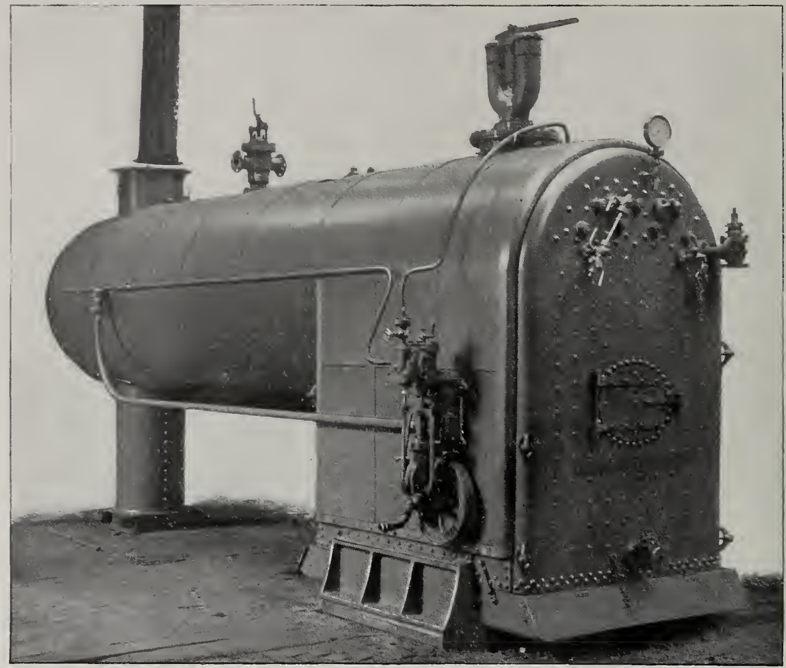
A PAIR OF LARGE LOCOMOTIVE BOILERS. BUILT BY MESSRS. ROBEY & CO., LTD.

ing in the fire and not in the water, inequalities in the firing or in the demand for steam which would pass unnoticed in a boiler of larger capacity make it difficult to maintain the steam at constant pressure and the water-level uniform, and careful watching is necessary. In many cases these boilers have to be supplemented by thermal storage vessels to lessen their sensitiveness in these respects.

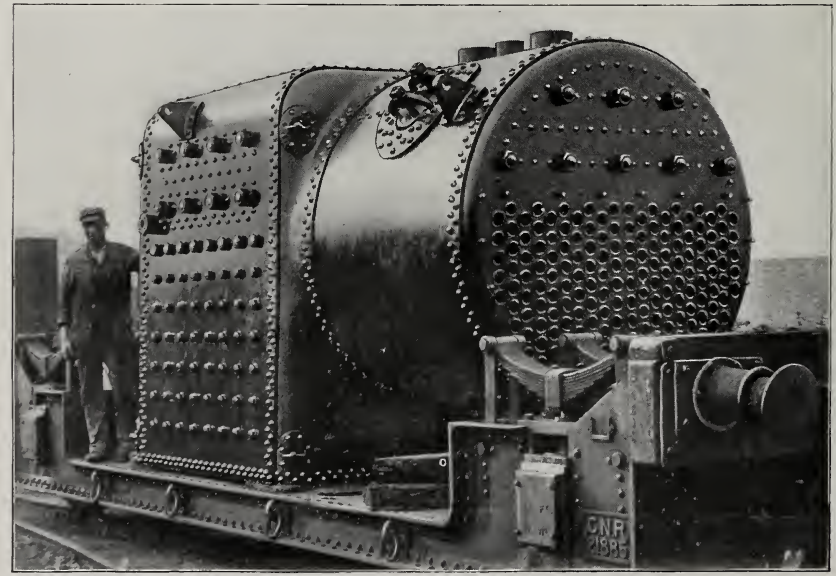
The water used in water-tube boilers has to be very pure, and some form of water-purifier should in every case be used, by which all mineral matter may be removed before the water enters the boiler. Scale or grease, which is injurious to all boilers, is fatal to these, and where surface condensers are used, grease filters are absolutely necessary for the reason that any impediment to the circulation in a narrow tube exposed to external heat may cause the tube to become filled with steam instead of water, leading to overheating and ultimately to the destruction of the tube. It is pointed out by the makers that they can be very speedily repaired. Experience seems to show that repairs are frequently necessary.

Against this it is only fair to say that the Babcock & Wilcox Company state that the average cost of up-keep of the boiler proper is less than two pence per horse-power per annum. Of the total number sold less than two per cent. have been thrown out of use, while a large number of their customers have repeated their orders, some a score of times.

The locomotive type boiler is a very compact and convenient form of steam generator, and is capable, when properly proportioned for the duty it has to perform, of giving very economical results. It is a remarkable tribute to the excellence of its original design that, through seventy years of active engineering progress, its form has remained unchanged; and it is, perhaps, not too much to say, seeing that no serious attempt has ever been made to supersede



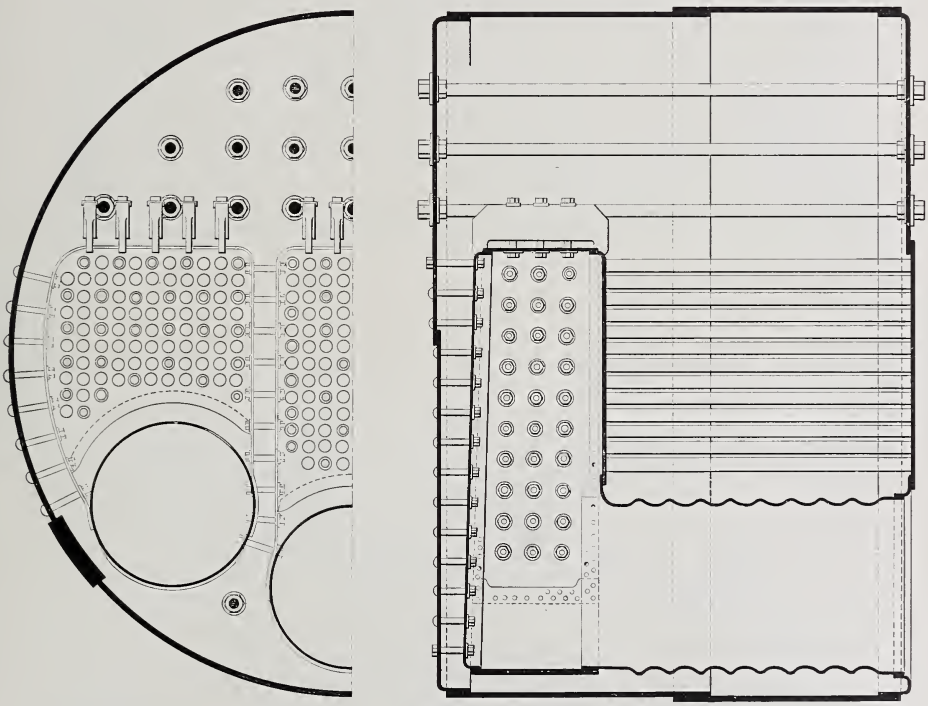
A LOCOMOTIVE TYPE BOILER. BUILT BY MESSRS. ROBEY & CO., LTD., LINCOLN



A BELPAIRE LOCOMOTIVE TYPE BOILER. BUILT BY MESSRS. ABBOTT & CO., LTD., NEWARK-ON-TRENT

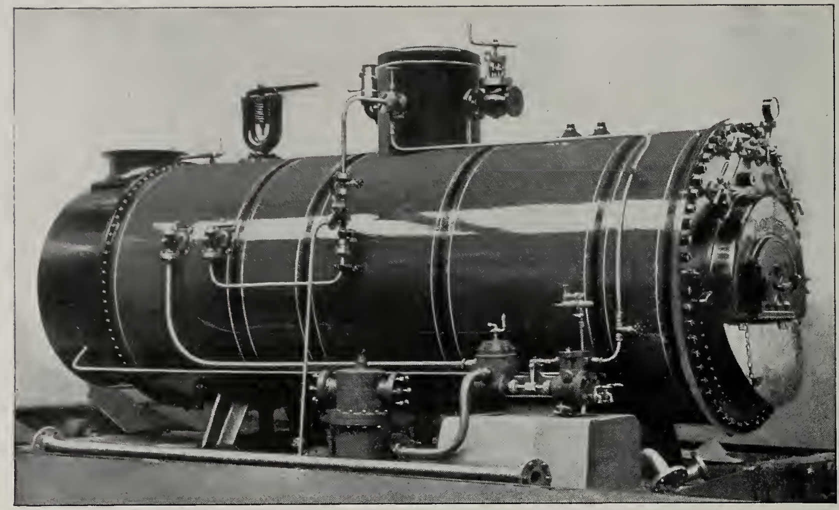
it in railway practice, that we owe to the locomotive boiler a good deal more of our material prosperity than we can easily realise.

But stationary locomotive type boilers such as we are now considering are commonly, and with good reason, built on a very different scale from those used for locomotive purposes. The difference is mainly in the extent of tube surface, as compared with the grate area. If we want a boiler which is to develop the maximum of possible power in a limited space; if we are prepared to put a highly-skilled fireman in charge, and to allow the requisite intervals for cleaning the fire and washing out the boiler, we turn unhesitatingly to locomotive practice and put in a boiler whose tube-surface is nearly or quite sixty times the grate area, knowing that the tremendous energy of the blast demands a corresponding increase in the amount of tube surface required to absorb the heat on its way to the chimney. But the ordinary locomotive type or stationary boiler for industrial purposes, working at a much slower rate, but continuously, for ten or twelve hours each day, with less skilled attendance, and probably inferior fuel, is usually allotted a tube-surface of about twenty-four times the grate area, with a fire-box surface of about five times the area of the grate. There is probably in the whole range of engineering nothing so elastic as the locomotive boiler; it is a willing horse which may be spurred to any extent by just contracting the area of the blast nozzle. Add to this its extreme portability; any locomotive type boiler,—and it is now made in very large sizes, as will be seen from the illustrations on pages 41 and 42,—can be rolled into a building, and set to work in a surprisingly short time; and we have before us probably the most useful all-round boiler ever devised.

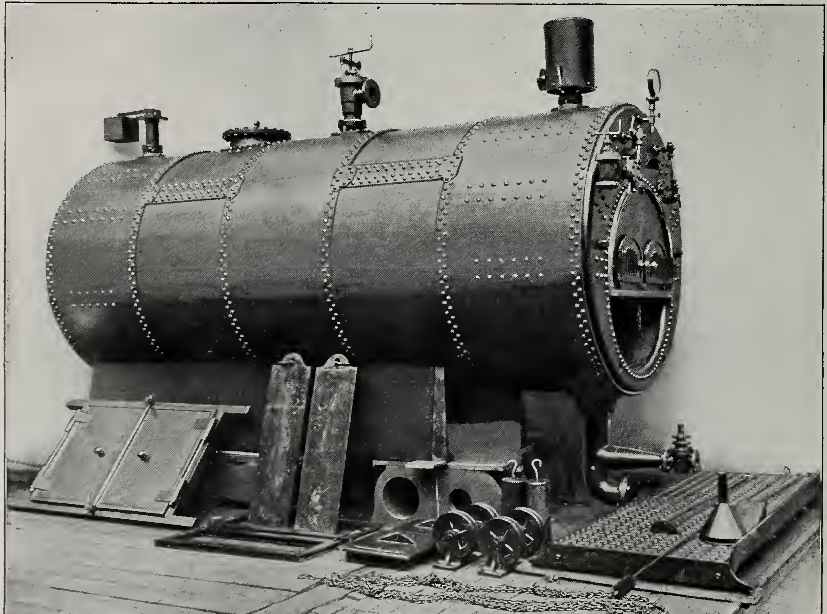


A MARINE, OR SCOTCH, BOILER. BUILT BY MESSRS. THOMAS RICHARDSON & SONS, LTD., HARTLEPOOL

Its disadvantages are the restricted steam space and the difficulty of effec-



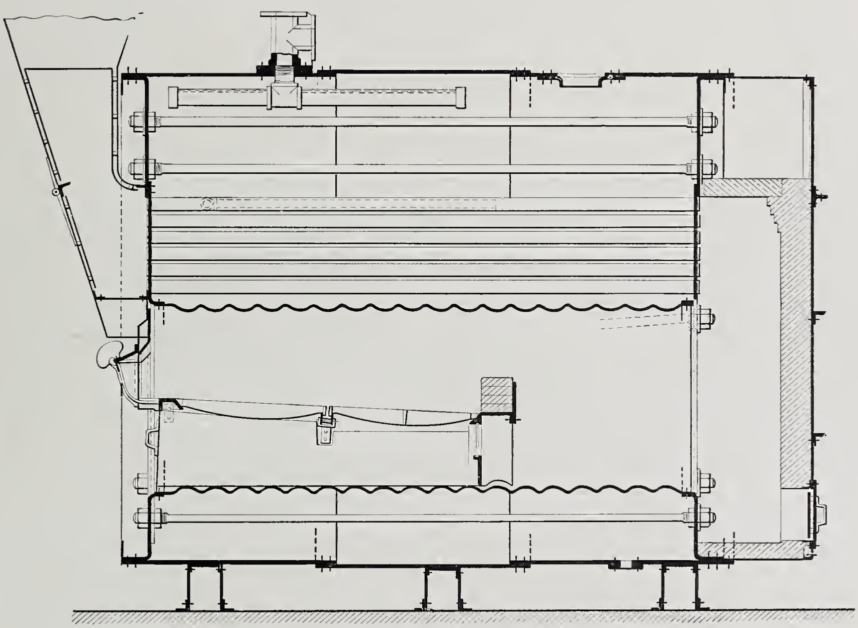
A DIRECT-TUBE INTERNALLY FIRED MULTITUBULAR BOILER



A SEMI-CORNISH MULTITUBULAR BOILER

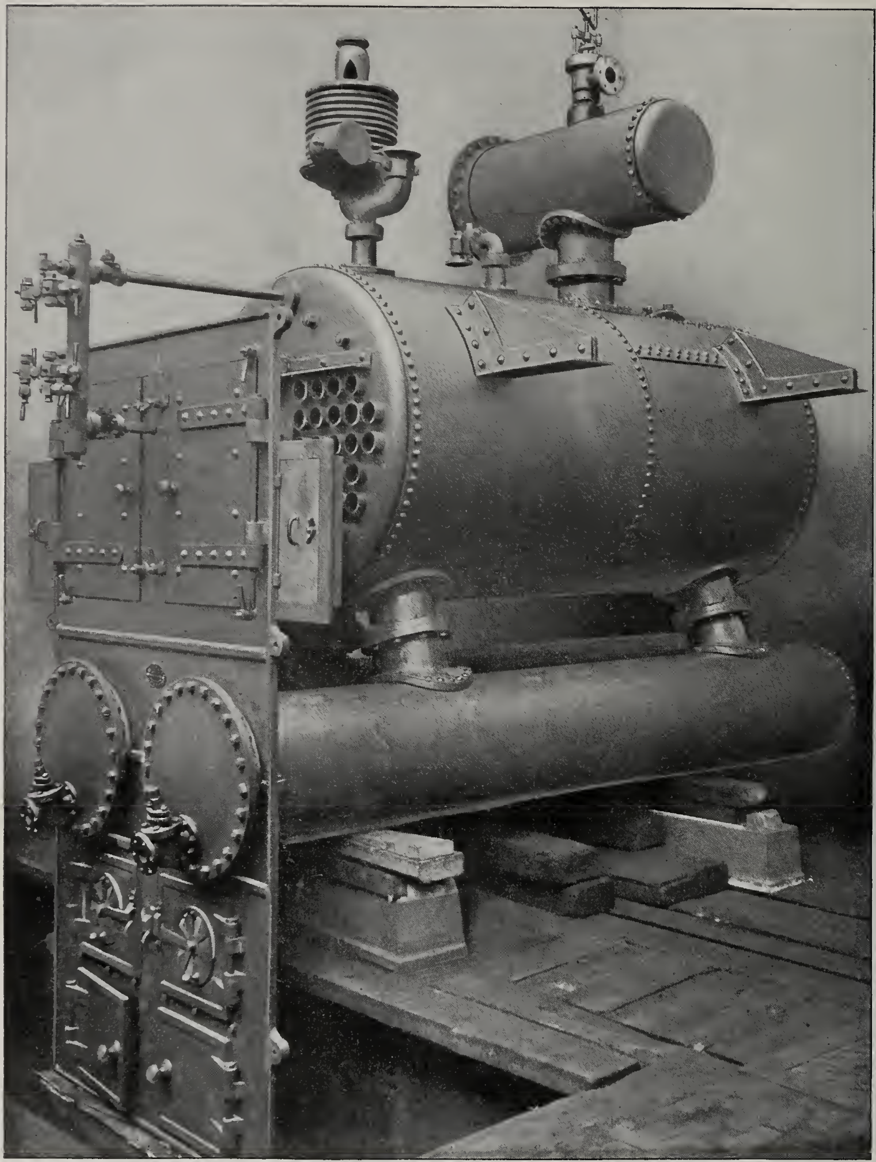
tively cleaning the narrow water spaces around the fire-box; it is not suitable for supplying steam to a long-stroke, slow-moving engine, the pulsations setting up induce a swaying movement in the water, and very little variation is permissible in the water level. But there seems no reason why these narrow water-spaces should be retained in cases where the boiler is not restricted in external dimensions.

There are no special developments to record in the locomotive boiler, if we except the Belpaire or square-topped fire-box, of which an example as a stationary boiler is illustrated on page 42, and the experiment, now being again tried, on two railways, of water-tubes in the fire-box. Neither of these inventions can, however, be described as "recent." The boilers of locomotive engines within the last two or three years have been enormously increased in size, and have, indeed, approached the limits of possibility in this direction; but the design remains unaltered, as to all appearance it will continue until the steam locomotive itself disappears from railways. Marine or Scotch boilers are now gaining favour for stationary purposes. A three furnace boiler of this class is shown on page 43, but the construction is so well known that no description is necessary. If not overworked, these boilers are very economical, and they occupy a very much smaller floor space than the Lancashire, about equal, in medium sizes, to that taken up by the water-tube type. In large sizes the marine boiler occupies relatively even less space, but the difficulties attending the transport of very large units are such as to greatly restrict their employment in inland situations.



A "DRY BACK" MULTITUBULAR BOILER

The Morison "Suspension" furnace, shown in the illustrations on page 43, embodies a most valuable application of the catenary curve, and differs entirely in principle from other forms of corrugated or ribbed furnaces. Imagine a flue made of some material such as canvas or sailcloth, comparatively strong in tension, but having no stiffness whatever! At equal intervals along the inside of this canvas tube place a series of



AN ELEPHANT MULTITUBULAR BOILER. BUILT BY MESSRS. ROBEY & CO., LTD.

hoops, and conceive the whole thing subjected to external air pressure in a closed chamber! The canvas sags or bulges inwards between the hoops in the same curve as that assumed by a chain suspended between two supports of equal height, and no excess of pressure can alter its form until the fabric gives way by tearing under the tensile stress. There is no crushing or collapse possible even with this unpromising material as long as the hoops, which form a series of circular arches, are strong enough to resist the compressive stress to which they alone are subjected. Carry this out in steel, making the narrow corrugated ribs deep enough to withstand the pressure, and you have

the Morison "Suspension" furnace! It forms the natural converse of the cylindrical boiler shell, and is as well adapted to resist collapse as the latter is to withstand a bursting stress.

The ordinary return-tube multitubular, or "dry-back," boiler has many features in common with the marine type, or Scotch, boiler, but is longer and smaller proportionately in diameter, and hence is better adapted for conveyance by rail. As its name implies, it has no internal combustion chamber, being fitted instead with a brick-lined smoke-box at the rear end, by which the products of combustion from the circular furnace (or furnaces) are returned through the small tubes to the up-take at the front.

In the United States this boiler occupies much the same position that the Lancashire does in Great Britain, and in large and small sizes is in extensive use. Considering its merits as a compact, durable and economical form of boiler, it is surprising that it is not more largely adopted here. Its construction is clearly shown on page 45. Like the locomotive type boiler, it is entirely self-contained, and requires no brickwork setting.

Another self-contained multitubular boiler is the direct-tubed, internally-fired boiler, which is practically a locomotive type boiler with a circular furnace. Frequently, as in the example illustrated at the top of page 44, the whole system of furnace, tubes and tube-plates can be withdrawn for cleaning, the two ends of the boiler being secured by bolts instead of rivets.

Yet another internally-fired multitubular boiler is the semi-Cornish, illustrated also on page 44, almost exactly similar to the last-named, but with a larger grate, and intended to be set in brick flues, just as a Cornish or Lancashire boiler would be, the greater part of the shell being utilised as further heating surface.

Externally-fired multitubular boilers have plain cylindrical shells with small tubes running from end to end. They are set in brick flues, and may be supported upon the walls of the setting by means of iron brackets riveted to the shell, or they may be slung by the same brackets to cast iron arches resting upon the top of the brickwork setting. These boilers are provided with a mud-drum at the rear end, away from the direct action of the fire.

Finally, there is the elephant multitubular boiler, shown in the illustration opposite, which finds much favour in some foreign countries.

The defect of all externally-fired boilers is the tendency to accumulate deposit from the water upon the lower inside surface of the shell immediately above the fire, thus leading to overheating and cracking. Hence these boilers should be used only with naturally pure, or purified, water.

THE PROGRESS IN STEAM NAVIGATION

By Sir William H. White,

Assistant Controller and Director of Naval Construction of the British Navy

Nothing more complete or more interesting has appeared within recent years concerning the progress in steam navigation than the presidential address delivered a short time ago by Sir William H. White before the Mechanical Science Section of the British Association. As stated by Sir William himself, it was proposed in this address to briefly review the characteristic features of this progress; to glance at the principal causes of advance in the speeds of steamships and in the lengths of the voyages on which such vessels can be successfully employed; and to indicate how the experience and achievement of the last sixty years bear upon the prospects of further advance. It needs, perhaps, scarcely to be added that the exposition of the subject was a masterly one. It afforded in condensed form a wealth of valuable historical and other information and has accordingly been presented here practically in full.—THE EDITOR.

STEAMSHIP design, to be successful, must always be based on experiment and experience as well as on scientific principles and processes. It involves problems of endless variety and great complexity. The services to be performed by steamships differ in character, and demand the production of many distinct types of ships and propelling apparatus. In all these types, however, there is one common requirement,—the attainment of a specified speed. And in all types there has been a continuous demand for higher speed.

Stated broadly, the task set before the naval architect in the design of any steamship is to fulfill certain conditions of speed in a ship which shall not merely carry fuel sufficient to traverse a specified distance at that speed, but which shall carry a specified load on a limited draught of water. Speed, load, power, and fuel supply are all related, and the two last have to be determined in each case. In some instances, other limiting conditions are imposed affecting length, breadth, or depth. In all cases there are three separate efficiencies to be considered,—those of the ship, as influenced by her form; of the propelling apparatus, including the generation of steam in the boilers and its utilisation in the engines; and of the propellers. Besides these considerations the designer has to take account of the materials and structural arrangements which will best secure the association of lightness with strength in the hull of the vessel. He must select those types of engines and boilers best adapted for the service proposed. Here the choice must be influenced by the length of the voyage, as well as the exposure it may involve to storm and stress.

Obviously the conditions to be fulfilled in an ocean-going passenger steamer of the highest speed, and in a cross-channel steamer designed to make short runs at high speed in comparatively sheltered waters, must be radically different. And so must be the conditions in a swift sea-going cruiser of large size and great coal endurance, from those best adapted for a torpedo-boat or destroyer. There is, in fact, no general rule applicable to all classes of steamships; each must be considered and dealt with independently, in the light of the latest experience and improvements. For merchant ships there is always the commercial consideration, Will it pay? For warships there is the corresponding inquiry, Will the cost be justified by the power and efficiency of the proposed ship?

CHARACTERISTICS OF PROGRESS IN STEAM NAVIGATION

Looking at the results so far attained, it may be said that progress in steam

navigation has been marked by the following characteristics:—(1) Growth in dimensions and weights of ships, and large increase in engine power as speeds have been raised. (2) Improvements in marine engineering, accompanying increase of steam pressure. Economy of fuel and reduction in the weight of propelling apparatus in proportion to the power developed. (3) Improvements in the materials used in shipbuilding; better structural arrangements; relatively lighter hulls and larger carrying power. (4) Improvements in form, leading to diminished resistance and economy of power expended in propulsion. These general statements represent well-known facts,—so familiar indeed that their full significance is often overlooked. It would be easy to multiply illustrations, but only a few representative cases will be taken.

TRANSATLANTIC PASSENGER STEAMERS

Transatlantic service naturally comes first. It is a simple case, in that the distance to be covered has remained practically the same, and that for most of the swift passenger steamers cargo-carrying capacity is not a very important factor in the design. In 1840 the Cunard steamship *Britannia*, built of wood, propelled by paddle-wheels, maintained a sea speed of about 8½ knots. Her steam pressure was 12 pounds per square inch. She was 207 feet long, about 2000 tons in displacement, her engines developed about 750 horse-power, and her coal consumption was about 40 tons per day, nearly 5 pounds of coal per indicated horse-power per hour. She had a full spread of sail. In 1871 the White Star steamship *Oceanic*,—first of that name,—occupied a leading position. She was iron-built, propelled by a screw, and maintained a sea-speed of about 14½ knots. The steam pressure was 65 pounds per square inch, and the engines were on the compound principle. She was 420 feet long, about 7200 tons in displacement, her engines developed 3000 horse-power, and she burnt about 65 tons of coal per day, or about 2 pounds per indicated horse-power per hour. She carried a considerable spread of sail. In 1889 the White Star steamer *Teutonic* appeared, propelled by twin screws, and practically with no sail power. She is steel-built, and maintains a sea speed of about 20 knots. The steam pressure is 180 pounds per square inch, and the engines are on the triple-expansion principle. She is about 565 feet long, 16,000 tons in displacement, 17,000 horse-power indicated, with a coal consumption of about 300 tons a day, or from 1.6 to 1.7-pound per indicated horse-power per hour. In 1894 the Cunard steamship *Campania* began her service, with triple-expansion engines, twin screws, and no sail power. She is about 600 feet long, 20,000 tons displacement, develops about 28,000 horse-power at full speed of 22 knots, and burns about 500 tons of coal per day. The new *Oceanic*, of the White Star Line, is just beginning her work. She is of still larger dimensions, being 704 feet in length, and over 25,000 tons displacement. From the authoritative statements made, it appears that she is not intended to exceed 22 knots in speed, and that the increase in size is to be largely utilised in additional carrying power. The latest German steamers for the transatlantic service are also notable. A speed of 22½-knots has been maintained by the *Kaiser Wilhelm der Grosse*, which is 25 feet longer than the *Campania*. Two still larger steamers are now building. The *Deutschland* is 660 feet long, and 23,000 tons displacement; her engines are to be of 33,000 horse-power, and it is estimated that she will average 23 knots. The other vessel is said to be 700 feet long, and her engines are to develop 36,000 horse-power, giving an estimated speed of 23½ knots. All these vessels have steel hulls and twin screws. It will be noted that to gain about 3 knots an hour nearly 50 per cent. will have been added to the displacement of the *Teutonic*, the engine power and coal consumption will be doubled, and the cost increased proportionately.

Sixty years of continuous effort and strenuous competition on this great "ocean ferry" may be summarised in

the following statement :—Speed has been increased from 8½ to 22½ knots; the time on the voyage has been reduced to about 38 per cent. of what it was in 1840. Ships have been more than trebled in length, about doubled in breadth, and increased tenfold in displacement. The engine power has been made forty times as great. The ratio of horse-power to the weight driven has been increased fourfold. The rate of coal consumption,—measured per horse-power per hour,—is now only about one-third what it was in 1840. To drive 2000 tons weight across the Atlantic at a speed of 8½ knots per hour, about 550 tons of coal were then burnt; now, to drive 20,000 tons across at 22 knots, about 3000 tons of coal are burnt.

With the low pressure of steam and heavy, slow-moving paddle-engines of 1840, each ton weight of machinery, boilers, etc., produced only about 2 horse-power. With modern twin-screw engines and high steam pressure, each ton weight of propelling apparatus produces from 6 horse-power to 7 horse-power. Had the old rate of coal consumption continued, instead of 3000 tons of coal, 9000 tons would have been required for a voyage at 22 knots. Had the engines been proportionately as heavy as those in use sixty years ago they would have weighed about 14,000 tons. In other words, machinery, boilers, and coals would have exceeded in weight the total weight of the *Campania* as she floats to-day. There could not be a more striking illustration than this of the close relation between improvements in marine engineering and the development of steam navigation at high speeds.

Equally true is it that this development could not have been accomplished but for the use of improved materials and structural arrangements. Wood, as the principal material for the hulls of high-powered swift steamers, imposed limits upon dimensions, proportions, and powers which would have been a bar to progress. The use of iron first, and since of steel, removed those limits. The percentage of the total displacement devoted to hull in a modern Atlantic liner of the largest size is not much, if at all, greater than was the corresponding percentage in the wood-built *Britannia* of 1840, of one-third the length and one-tenth the total weight. Nor must it be overlooked that with increase in dimensions have come considerable improvements in form favouring economy in propulsion. This is distinct from the economy resulting from increase in size, which Brunel appreciated thoroughly half a century ago when he designed the *Great Britain* and the *Great Eastern*.

The importance of a due relation between the lengths of the "entrance and run" of steamships and their intended maximum speeds, and the advantages of greater length and fineness of form as speeds are increased, were strongly insisted upon by Scott Russell and Froude. Naval architects, as a matter of course, now act upon the principle, so far as other conditions permit. For it must never be forgotten that economy of propulsion is only one of many desiderata which must be kept in view in steamship design. Structural weight and strength, seaworthiness, and stability all claim attention, and may necessitate modifications in dimensions and form which do not favour the maximum economy of propulsion. Increase in length and weight have largely assisted the marvellous regularity of service now attained on the longest passages by swift steamships. Even the largest vessels at times have to yield to the forces of nature displayed in wind and sea. But these conditions are more rarely reached in the longer and heavier ships.

SWIFT PASSENGER STEAMERS FOR LONG VOYAGES

Changes similar to those described for the transatlantic service have been in progress on all the great lines of ocean traffic. In many instances increase in size has been due not only to increase in speed, but to enlarged carrying power, and the extension of the lengths of voyages. No distance is now found too great for the successful working of steamships, and the sailing fleet is rapidly diminishing in importance. So far

as long-distance steaming is concerned, the most potent factor has undoubtedly been the marvellous economy of fuel that has resulted from higher steam pressures and greater expansion. In all cases, however, advances have been made possible not merely by economy of fuel, but by improvements in form, structure, and propelling apparatus, and by increased dimensions. This might be illustrated by many interesting facts drawn from the records of the great steamship companies which perform the services to the Far East, Australia, South America, and the Pacific. I must be content, however, with the statement of a few facts regarding the development of the fleet of the Peninsular and Oriental Company. The paddle steamer *Willam Fawcett*, of 1829, was about 75 feet long, 200 tons displacement, of 60 nominal horse-power, —probably about 120 indicated horse-power, — and in favourable weather steamed at a speed of 8 knots. Her hull was of wood, and, like all the steamers of that date, she had considerable sail power.

In 1853 the *Himalaya*, iron-built screw steamer of this line, was described as "of larger dimensions than any then afloat, and of extraordinary speed." She was about 340 feet long, over 4000 tons load displacement, 2000 indicated horse-power on trial, with an average sea-speed of about 12 knots. The steam pressure was 14 pounds per square inch, and the daily coal consumption about 70 tons. This vessel was transferred to the Royal Navy, and did good service as a troopship for forty years. In 1893 another *Himalaya* was added to the company's fleet. She was steel-built, nearly 470 feet long and 12,000 tons load displacement, with over 8000 indicated horse-power and a capability to sustain 17 to 18 knots at sea, on a daily consumption of about 140 tons of coal. The steam pressure is 160 pounds per square inch, and the engines are of the triple-expansion type. Comparing the two *Himalayas*, it will be seen that in forty years the length has been increased about 40 per cent., displacement trebled, horse-power quadrupled, and speed increased 50 per cent. The proportion of horse-power to displacement has only been increased as three to four, enlarged dimensions having secured relative economy in propulsion. The rate of coal consumption has been probably reduced to about one-third of that in the earlier ship. The latest steamers of the line are of still larger dimensions, being 500 feet long and of proportionately greater displacement. It is stated that the *Himalaya* of 1853 cost £132,000 complete for sea; the corresponding outlay on her successors is not published, but it is probably twice as great.

On the service to the Cape similar developments have taken place. Forty years ago vessels less than 200 feet long and about 7 knots performed the service, whereas the latest additions to the fleets exceed 500 feet in length, and can, if required, be driven at 17 to 18 knots, ranking in size and power next to the great transatlantic liners. Commercial considerations necessarily regulate what is undertaken in the construction of merchant steamers, including the swift vessels employed in the conveyance of passengers and mails. The investment of £600,000 to £700,000 in a single vessel like a great transatlantic liner is obviously a serious matter for private owners; and even the investment of half that amount in a steamer of less dimensions and speed is not to be lightly undertaken. It is a significant fact that, whereas fifteen years ago nearly all the largest and swiftest ocean steamers were British built and owned, at the present time there is serious competition in this class by German, American, and French companies. It is alleged that this change has resulted from the relatively large subsidies paid by foreign governments to the owners of swift steamers; and that British owners, being handicapped in this way, cannot continue the competition in size and speed on equal terms unless similarly assisted. This is not the place to enter into any discussion of such matters. But they obviously involve greater considerations than the profit of shipowners, and have a bearing on the naval defence of the Empire. In 1887 the government rec-

ognised this fact, and made arrangements for the subvention and armament of a number of the best mercantile steamships for use as auxiliary cruisers. Since then other nations have adopted the policy, and given such encouragement to their shipowners that the numbers of swift steamers suitable for employment as cruisers have been largely increased. Not long since the First Lord of the Admiralty announced to Parliament that the whole subject was again under consideration.

CARGO AND PASSENGER STEAMERS

Cargo steamers, no less than passenger steamers, have been affected by the improvements mentioned. Remarkable developments have occurred recently, not merely in the purely cargo carrier, but in the construction of vessels of large size and good speed, carrying very great weights of cargo and considerable numbers of passengers. The much-decried "ocean tramp" of the present day exceeds in speed the passenger and mail steamer of fifty years ago. Within ten years vessels in which cargo-carrying is the chief element of commercial success have been increased in length from 300 feet or 400 feet to 500 feet or 600 feet; in gross register tonnage from 5000 to over 13,000 tons, and in speed from 10 or 12 knots to 15 or 16 knots. Vessels are now building for the Atlantic service which can carry 12,000 to 13,000 tons dead-weight, in addition to passengers, while possessing a sea-speed as high as that of the swiftest mail steamers afloat in 1880. Other vessels of large carrying power and good speed are running on much longer voyages, such as to the Cape and Australia.

In order to work these ships successfully, very complete organisation is necessary for the collection, embarkation, and discharge of cargo. The enterprise and skill of shipowners have proved equal to this new departure, as they have in all other developments of steamships. How much further progress will be made in the sizes and speeds of these mixed cargo and passenger steamers cannot be foreseen. The limits will be fixed by commercial considerations, and not by the capability of the shipbuilder. In passing, it may be noted that while the lengths and breadths of steamships have been greatly increased, there has been but a moderate increase in draught. Draught of water is, of course, practically determined by the depths available in the ports and docks frequented, or in the Suez Canal for vessels trading to the East. From the naval architect's point of view increase in draught is most desirable as favouring increase of carrying power and economy of propulsion. This fact has been strongly represented by shipowners and ship designers, and not without result. The responsible authorities of many of the principal ports and of the Suez Canal have taken action towards giving greater depth. Other changes have become necessary on the part of dock and port authorities in consequence of the progress made in shipbuilding. Docks and dock entrances have had to be increased in size, more powerful lifting appliances provided, and large expenditure incurred. There is no escape from these changes if the trade of a port is to be maintained. The chief lesson to be learnt from past experience is that when works of this character are planned, it is wise to provide a large margin beyond the requirements of existing ships.

CROSS-CHANNEL STEAMERS

The conditions to be fulfilled in vessels designed to steam at high speed for limited periods obviously differ essentially from those holding good in ocean-going steamers. None the less interest attaches, however, to cross-channel steamers, and in no class has more notable progress been made. So far as I am informed, the first steamer placed on the route between Dover and the Continent in 1821 was of 90 tons burden, 30 horse-power nominal, and maintained a speed of 7 to 8 knots. She was built by Denny, of Dumbarton, engined by Robert Napier, and named the *Rob Roy*. It is interesting to note that the lineal successors of the builder of this pioneer vessel have produced some of the most recent and swiftest additions to the cross-channel service. In 1861-2

a notable advance was made by the building of vessels which were then remarkable for structure and speed, although small and slow when compared with vessels now running. Their designers realised that lightness of hull was of supreme importance, and with great trouble and expense obtained steel of suitable quality. The machinery was of special design, and relatively light for the power developed. A small weight of coal and cargo had to be carried, and the draught of water was kept to about 7 feet. Under then existing conditions it was a veritable triumph to attain speeds of 15 to 16 knots in vessels only 190 feet long, less than 25 feet broad, and under 350 tons in displacement. To raise the trial speed to 21 or 22 knots in later vessels, whose design includes the improvements of a quarter of a century, it has been found necessary to adopt lengths exceeding 320 feet, and breadths of about 35 feet, with engines developing 4500 to 6000 indicated horse-power, and with very great increase in coal consumption and cost.

Another interesting contrast is to be found in the comparison of the steamers running between Holyhead and Kingstown in 1860 and at the present time. The *Leinster* of 1860 was 328 feet long, 35 feet broad, and rather less than 13 feet draught. Her trial displacement was under 2000 tons, and with 4750 horse-power she made 17¾ knots. She had a steam pressure of 25 pounds per square inch, and was propelled by paddle-wheels driven by slow-moving engines of long stroke. Her successor of 1896 is about 30 feet greater length, 6½ feet greater breadth, and about 10 per cent. greater displacement. The steam pressure is 160 pounds per square inch. Forced draught is used in the stokehold. Twin screws are adopted, driven by quick-running vertical engines of the triple-expansion type. Very great economy of coal consumption is thus secured, as compared with the earlier vessel, and much lighter propelling apparatus in proportion to the power, which is from 8000 horse-power to 9000 horse-power at the full speed of 23 knots. The hull is built of steel, and is proportionately lighter.

This is a typical case, and illustrates the effect of improvements in shipbuilding and engineering in thirty-five years. The later ship probably requires to carry no greater load of coal than, if so great, as her predecessor, although her engine power is nearly double. The weight devoted to propelling machinery and boilers is probably not so great. Thanks to the use of steel instead of iron, and to improved structural arrangements, the weight of hull is reduced in comparison with dimensions, and a longer ship is produced better adapted to the higher speed. Messrs. Laird, of Birkenhead, who built three of the *Leinster* class forty years ago, and have built all the new vessels, are to be congratulated on their complete success. Between such vessels designed for short runs at high speed, and requiring therefore to carry little coal, while the load carried, exclusive of coal, is trifling, and an ocean-going steamer of the same average speed designed to make passages of 3000 miles, there can obviously be little in common. But equal technical skill is required to secure the efficient performance of both services. In the cross-channel vessel, running from port to port and under constant observation, conditions of working in engine and boiler-rooms, as well as relative lightness in scantlings of hull, can be accepted which would be impossible of application in the sea-going ship. These circumstances, in association with the small load carried, explain the apparent gain in speed of the smaller vessel in relation to her dimensions.

INCREASE IN SIZE AND SPEED OF WARSHIPS

Turning from sea-going ships of the mercantile marine to warships, one finds equally notable facts in regard to increase in speed, associated with enlargement in dimensions and advance in propelling apparatus, materials of construction, structural arrangements, and form. Up to 1860 a measured-mile speed of 12 to 13 knots was considered sufficient for battleships and the largest classes of

cruisers. All these vessels possessed good sail power, and used it freely as an auxiliary to steam or as an alternative when cruising or making passages. When armoured battleships were built, —1859,—the speeds on measured-mile trials were raised to 14 or 14½ knots, and so remained for about twenty years. Since 1880 the speeds of battleships have been gradually increased, and in the latest types the measured-mile speed required is 19 knots. Up to 1870 the corresponding speeds in cruisers ranged from 15 to 16 knots. Ten years later the maximum speeds were 18 to 18½ knots in a few vessels. Since then trial speeds of 20 to 23 knots have been attained, or are contemplated. There is, of course, a radical distinction between these measured-mile performances of warships and the average sea speeds of merchant steamers above described. But for purposes of comparison between warships of different dates measured-mile trials may fairly be taken as the standard. For long-distance steaming the power developed would necessarily be much below that obtained for short periods, and with everything at its best. This is frankly recognised by all who are conversant with warship design, and fully allowed for in estimates of sea speeds.

On the other hand, it is possible to point to sea trials made with recent types where relatively high speeds have been maintained for long periods. For example, the battleship *Royal Sovereign* has maintained an average speed of 15 knots from Plymouth to Gibraltar, and the *Renown* has maintained an equal speed from Bermuda to Spithead. As instances of good steaming by cruisers, reference may be made to 60-hour trials with the *Terrible*, when she averaged over 20 knots, and to the run home from Gibraltar to the Nore by the *Diadem*, when she exceeded 19 knots. Vessels of the *Pelorus* class of only 2100 tons displacement have made long runs at sea averaging over 17 knots. Results such as these represent a substantial advance in speed of Her Majesty's ships in recent years.

Similar progress has been made in foreign warships built abroad as well as in this country. It is not proposed to give any facts for these vessels, or to compare them with results obtained by similar classes of ships in the Royal Navy. Apart from full knowledge of the conditions under which speed trials are made, a mere statement of speeds attained is of no service. One requires to be informed accurately respecting the duration of the trial, the manner in which engines and boilers are worked, the extent to which boilers are "forced," or the proportion of heating surface to power indicated, the care taken to eliminate the influence of tide or current, the mode in which the observations of speed are made, and other details, before any fair or exact comparison is possible between ships. For present purposes, therefore, it is preferable to confine the illustrations of increase in speed in warships to results obtained under Admiralty conditions, and which are fairly comparable.

A great increase in size has accompanied this increase in speed, but it has resulted from other changes in modern types, as well as from the rise in speed. Modern battleships are of 13,000 to 15,000 tons, and modern cruisers of 10,000 to 14,000 tons, not merely because they are faster than their predecessors, but because they have greater powers of offence and defence, and possess greater coal endurance. Only a detailed analysis, which cannot now be attempted, could show what is the actual influence of these several changes upon size and cost, and how greatly the improvements made in marine engineering and shipbuilding have tended to keep down the growth in dimensions consequent on increase in load carried, speed attained, and distance traversed. It will be noted also that large as are the dimensions of many classes of modern warships, they are all smaller in length and displacement than the largest mercantile steamers above described. There is, no doubt, a popular belief that the contrary is true, and that warships exceed merchant ships in tonnage. This arises from the fact that merchant ships are ordinarily described, not by their dis-

placement tonnage, but by their registered tonnage, which is far less than their displacement.

As a matter of fact, the largest battleships are only of about two-thirds the displacement of the largest passenger steamers, and from 200 feet to 300 feet shorter. The largest cruisers are from 100 feet to 200 feet shorter than the largest passenger steamers, and about 60 per cent. of their displacement. In breadth the warships exceed the largest merchant steamers by from 5 feet to 10 feet. This difference in form and proportions is the result of radical differences in the vertical distribution of the weights carried, and is essential to the proper stability of the warships. Here we find an illustration of the general principle underlying all ship designing. In selecting the forms and proportions of a new ship considerations of economical propulsion cannot stand alone. They must be associated with other considerations, such as stability, protection, and manœuvring power, and in the final result economy of propulsion may have to be sacrificed to some extent in order to secure other essential qualities.

ADVANTAGES OF INCREASED DIMENSIONS

Before passing on it may be interesting to illustrate the gain in economy of propulsion resulting from increase in dimensions by means of the following table which gives particulars of a number of typical cruisers, all of comparatively recent design:—

	No. 1.	No. 2	No. 3.	No. 4.	No. 5.
Length, feet	280	300	360	435	500
Breadth, feet	35	43	60	69	71
Mean draught, feet	13	16½	23¾	24½	26¼
Displacement, tons	1,800	3,400	7,400	11,000	14,200
Indicated horse-power for 20 knots	6,000	9,000	11,000	14,000	15,500
Indicated horse-power per ton of displacement	3.3	2.65	1.48	1.27	1.09

The figures given are the results of actual trials, and embody, therefore, the efficiencies of propelling machinery, propellers, and forms of the individual ships. Even so they are instructive. Comparing the first and last, for example, it will be seen that while the displacement is increased nearly eightfold, the power for 20 knots is only increased about 2.6 times. If the same types of engines and boilers had been adopted in these two vessels,—which was not the case, of course,—the weights of propelling apparatus and coal for a given distance would have been proportional to the respective powers; that is to say, the larger vessel would have been equipped with only 2.6 times the weight carried by the smaller. On the other hand, roughly speaking, the disposable weights, after providing for hulls and fittings in these two vessels, might be considered to be proportional to their displacements. As a matter of fact, this assumption is distinctly in favour of the smaller ship. Adopting it, the larger vessel would have about eight times the disposable weight of the smaller; while the demand for propelling apparatus and fuel would be only 2.6 times that of the smaller vessel. There would, therefore, be an enormous margin of carrying power in comparison with displacement in the larger vessel. This might be devoted, and, in fact, was devoted, partly to the attainment of a speed considerably exceeding 20 knots, —which was a maximum for the smaller vessel,—partly to increased coal endurance, and partly to protection and armament.

Another interesting comparison may be made between vessels Nos. 4 and 5 in the preceding table, by tracing the growth in power necessary to drive the vessels at speeds ranging from 10 knots up to 22 knots.

It will be noted from the table on the opposite page that up to the speed of 18 knots there is a fairly constant ratio between the powers required to drive the two ships. As the speeds are increased the larger ship gains, and at 22 knots the same power is required in both ships. The smaller vessel, as a matter of fact, was designed for a maximum speed of 20½ knots, and the larger

for 22 knots. Unless other qualities had been sacrificed neither space nor weight could have been found in the smaller vessel for machinery and coals corresponding to 22 knots. The figures

Knots.	No. 4. Horse-power.	No. 5. Horse-power.
10	1,500	1,800
12	2,500	3,100
14	4,000	5,000
16	6,000	7,500
18	9,000	11,000
20	14,000	15,500
22	23,000	23,000

are interesting, however, as illustrations of the principle that economy of propulsion is favoured by increase in dimensions as speeds are raised.

Going a step further, it may be assumed that in unsheathed cruisers of this class about 40 per cent. of the displacement will be required for the hull and fittings, so that the balance, or "disposable weight," would be about 60 per cent., say, 6600 tons for the smaller vessel, and 8500 tons for the larger, a gain of nearly 2000 tons fo the latter. If the speed of 22 knots were secured in both ships, with machinery and boilers of the same type, the larger ship would, therefore, have about 2000 tons greater weight available for coals, armament, armour, and equipment. These illustrations of well-known principles have been given simply for the assistance of those not familiar with the subject, and they need not be carried further. More general treatment of the subject, based on experimental and theoretical investigation, will be found in text-books of naval architecture.

SWIFT TORPEDO VESSELS

Torpedo flotillas are comparatively recent additions to war fleets. The first torpedo-boat was built by Mr. Thornycroft for the Norwegian Navy in 1873; and the same gentleman built the first torpedo-boat for the Royal Navy in 1877. The construction of the larger class, known as "torpedo-boat destroyers," dates from 1893. These various classes furnish some of the most notable examples extant of the attainment of extraordinarily high speeds for short periods, and in smooth water, by vessels of small dimensions. Their qualities and performances, therefore, merit examination. Mr. Thornycroft may justly be considered the pioneer in this class of work. Greatly impressed by the combination of lightness and power embodied in railway locomotives, Mr. Thornycroft applied similar principles to the propulsion of small boats, and obtained remarkably high speeds. His work became more widely known when the results were published of a series of trials, conducted in 1872 by Sir Frederick Bramwell, on a small vessel named the *Miranda*. She was only 45 feet long, and weighed four tons, yet she exceeded 16 knots on trial. The Norwegian torpedo-boat, built in 1873, was 57 feet long, 7½ tons, and of 15 knots; the first English torpedo-boat of 1877 was 81 feet long, 29 tons, and attained 18½ knots.

Mr. Yarrow also undertook the construction of small, swift vessels at a very early date, and has greatly distinguished himself throughout the development of the torpedo flotilla. Messrs. White, of Cowes, previously well known as builders of steamboats for use on board ships, extended their operations to the construction of torpedo-boats. These three firms for a considerable time practically monopolised this special class of work in this country. Abroad they had able competitors in Normand in France, Schichau in Germany, and Herreshoff in the United States. Keen competition led to successive improvements, and rapid rise in speed.

During the last six years the demand for a fleet of about one hundred destroyers, to be built in the shortest possible time, involved the necessity for increasing the sources of supply. At the invitation of the Admiralty a considerable number of the leading shipbuilding and engineering firms have undertaken, and successfully carried through, the construction of destroyers varying from 26 to 33 knots in speed, although the work was necessarily of a novel character, involving many difficulties. As the speeds of torpedo vessels have risen, so have their dimensions increased. Within the class, the law shown to hold good in

larger vessels applies equally. In 1877 a first-class torpedo-boat was 81 feet long, under 30 tons weight, developed 400 horse-power, and steamed 18½ knots. Ten years later the corresponding class of boat was 135 feet long, 125 tons weight, developed 1500 horse-power, and steamed 23 knots. In 1897 it had grown to 150 feet in length, 140 to 150 tons, 2000 horse-power, and 26 knots. Destroyers are not yet of seven years' standing, but they come under the rule. The first examples,—1893,—were 180 feet long, 240 tons, 4000 horse-power, and 26 to 27 knots. They were followed by 30-knot vessels, 200 feet to 210 feet long, 280 to 300 tons, 5500 to 6000 horse-power. Vessels now in construction are to attain 32 to 33 knots, their lengths being about 230 feet, displacements 360 to 380 tons, and engine power 8000 to 10,000 horse-power.

Cost has gone up with size and power, and the limit of progress in this direction will probably be fixed by financial considerations, rather than by constructive difficulties, great as these are as speeds rise. It may be interesting to summarise the distinctive features of torpedo vessel design.

(1) The propelling apparatus is excessively light in proportion to the maximum power developed. Water-tube boilers are now universally adopted, and on speed trials they are "forced" to a considerable extent. High steam pressures are used. The engines are run at a high rate of revolution,—often at 400 revolutions per minute. Great care is taken in every detail to economise weight. Speed trials at maximum power extend over only three hours. On such trials in a destroyer each ton weight of propelling apparatus produces about 45 indicated horse-power. Some idea of the relative lightness of the destroyer's machinery and boilers will be obtained when it is stated that in a large modern cruiser with water-tube boilers, high steam pressure, and quick-running engines, the maximum power obtained on an eight hours' trial corresponds to about 12 indicated horse-power per ton of engines, boilers, etc. That is to say, the proportion of power to weight of propelling apparatus is from three and a half to four times as great in the destroyer as it is in the cruiser.

(2) A very large percentage of the total weight,—or displacement,—of a torpedo vessel is assigned to propelling apparatus. In a destroyer of 30 knots trial speed, nearly one-half the total weight is devoted to machinery, boilers, etc. In the swiftest cruisers of large size, the corresponding allocation of weight is less than 20 per cent. of the displacement, and in the largest and fastest mail steamers it is about 20 to 25 per cent.

(3) The torpedo vessel carries a relatively small load of fuel, equipment, etc. Taking a 30-knot destroyer, for example, the speed trials are made with a load not exceeding 12 to 14 per cent. of the displacement. In a swift cruiser the corresponding load would be from 40 to 45 per cent., or proportionately more than three times as great. What this difference means may be illustrated by two statements. If the load were trebled, and the vessel correspondingly increased in draught and weight, the speed attained with the same maximum power would be about three knots less. If, on the other hand, the vessel were designed to attain 30 knots on trial with the heavier load, her displacement would probably be increased about 70 to 80 per cent.

(4) The hull and fittings of the torpedo vessel are exceedingly light in relation to the dimensions and engine power. For many parts of the structure steel of high tensile strength is used. Throughout the utmost care is taken to economise weight. In small vessels, for special service, many conditions can be accepted which would be inadmissible in larger sea-going vessels. The result of all this care is the production of hull-structures having ample general strength, but very little local strength; but notwithstanding all the accidents of navigation and collisions that have occurred in this class of vessel,—and they have not been few,—not one has yet foundered at sea.

These conditions are essential to the

attainment of very high speeds for short periods. They resemble the conditions ruling the design of cross-channel steamers, so far as relative lightness of propelling apparatus, small load, and light scantlings are concerned. The essential differences lie in the requirements for passenger accommodation as compared with the requirements for armament of the torpedo vessel. No one has yet proposed to extend the torpedo vessel system to sea-going ships of large dimensions. Very similar conditions for the propelling apparatus have been accepted in a few cruisers of considerable dimensions, wherein high speeds for short periods were required. It is, however, unquestionable that in many ways, and particularly in regard to machinery design, the construction of torpedo vessels has greatly influenced that of larger ships.

One important consideration must not be overlooked. For short-distance steaming at high speeds economy in coal consumption is of little practical importance, and it is all-important to secure lightness of propelling apparatus in relation to power. For long-distance steaming, on the contrary, economy in coal consumption is of primary importance; and savings in weight of propelling apparatus, even of considerable amount, may be undesirable if they involve increased coal consumption. Differences of opinion prevail as to the real economy of fuel obtainable with boilers and engines such as are fitted to torpedo vessels. Claims are made for some vessels which represent remarkable economy. Only enlarged experience can settle these questions. Endurance is also an important quality in sea-going ships of large size; not merely in structure, but in propelling apparatus. The extreme lightness essential in torpedo vessels obviously does not favour endurance, if high powers are frequently or continuously required. Still it cannot be denied that the results obtained in torpedo vessels show such a wide departure from those usual in sea-going ships as to suggest the possibility of some intermediate type of propelling apparatus applicable to large sea-going ships, and securing sufficient durability and economy of fuel in association with further savings of weight.

THE PARSONS TURBO-MOTOR

The steam turbo-motor, introduced by Mr. Charles Parsons, with its very high rate of revolution, reduces the weights of machinery, shafting, and propellers greatly below the weight required in the quickest running engines of the reciprocating type. This reduction in the proportion of weight to power carries with it, of course, the possibility of higher speed in a vessel of given dimensions, and when large powers are employed the absolute gain is very great. An illustration of this has been given by Mr. Parsons in the *Turbinia.* That remarkable vessel is 100 feet long, and of 44½ tons displacement, but she has attained 33 to 34 knots in short runs. There are three shafts, each carrying three screw propellers, each shaft driven by a steam turbine making over 2000 revolutions at full speed, when an aggregate of more than 2000 horse-power is developed. A water-tube boiler of special design supplies steam of 175 pounds pressure, and is exceptionally light for the steam produced, being highly forced.

The whole weight of machinery and boilers is 22 tons; in other words, about 100 horse-power indicated is produced for each ton weight of propelling apparatus. This is rather more than twice the proportion of power to weight as compared with the lightest machinery and boilers fitted in torpedo-boats and destroyers. It will be noted that in the *Turbinia*, as in the destroyers, about half the total weight is devoted to propelling apparatus, and in both instances the load carried is relatively small. The secret of the extraordinary speed is to be found in the extreme lightness of propelling apparatus, and small load. No doubt in the *Turbinia* lightness has been pushed further than it would be in vessels of larger size and greater power. In such vessels a lower rate of revolution would probably be accepted, additional motors would be fitted for manœuvring and going astern, boilers of relatively

greater weight would be adopted, and other changes made. But after making ample allowance for all such increases in weight, it is unquestionable that considerable economies must be possible with rotary engines. Two other vessels of the destroyer type with turbo-motors,—one for the Royal Navy,—are now approaching completion. Their trials will be of great interest, as they will furnish a direct comparison with vessels of similar size and form, fitted with similar boilers and driven by reciprocating engines.

On the side of coal consumption Mr. Parsons claims at least equality with the best triple-expansion engines. Into the other advantages attending the use of rotary engines it is not necessary now to enter. Reference must be made, however, to one matter in which Mr. Parsons has done valuable and original work. In torpedo vessels of high speed the choice of the most efficient propellers has always been a matter of difficulty, and the solution of the problem has in many instances involved extensive experimental trials. By means of alterations in propellers alone very large increases in speed have been effected; and, even now, there are difficulties to be faced. When Mr. Parsons adopted the extraordinary speed of revolution just named for the *Turbinia* he went far beyond all experience and precedent, and had to face unknown conditions. He has found the solution, after much patient and original investigation, in the use of multiple screws of small diameter. His results in this direction are of general interest to all who have to deal with screw propulsion. Such radical changes in propelling machinery as are involved in the adoption of turbo-motors must necessarily be subjected to thorough test before they will be widely adopted. The experiment which the Admiralty are making is not on a small scale as regards power. Although it is made in a destroyer, about 10,000 horse-power will probably be developed, and a correspondingly high speed attained. It may well happen that from this experiment very far-reaching effects may follow. Mr. Parsons himself has prepared many designs illustrating various applications of the system to sea-going, cross-channel and special service vessels. Where shallowness of draught is unavoidable, the small diameter of the screws possible with the quick-running turbines is clearly an important matter.

COMPARISONS BETWEEN LARGE AND SMALL VESSELS

It has been shown that the attainment of very high speeds by vessels of small size involves many conditions not applicable to large sea-going steamships. But it is equally true that in many ways the trials of small, swift vessels constitute model experiments, from which interesting information may be obtained as to what would be involved in driving ships of large size at speeds much exceeding any of which we have experience. When the progressive steam trials of such small vessels can be studied, side by side with experiments made an models to determine their resistance to various speeds, then the fullest information is obtained, and the best guide to progress secured. This advantage, as has been said, we owe to William Froude. His contributions to the "Reports" of the British Association are classics in the literature of the resistance and propulsion of ships. In 1874 he practically exhausted the subject of frictional resistance so far as it is known, and his presidential address in 1875 dealt fully and lucidly with the modern or stream-line theory of resistance. No doubt there would be advantage in extending Froude's experiments on frictional resistance to greater lengths and to ship-shaped forms. It is probable also that dynamometric determinations of the resistance experienced by ships of modern forms and considerable size when towed at various speeds would be of value if they could be conducted.

These extensions of what Froude accomplished are not easily carried out, and in this country the pressure of work on shipbuilding for the Royal Navy has for many years past taxed to the utmost limits the capacity of the Admiralty experimental establishment, so ably super-

intended by Mr. R. E. Froude, allowing little scope for purely scientific investigations, and making it difficult to deal with the numerous experiments incidental to the designs of actual ships. Now that Holland, Russia, Italy, and the United States have equipped experimental establishments, while Germany and France are taking steps in that direction, we may hope for extensions of purely scientific work and additions to our knowledge. In this direction, however, I am bound to say that much might be done if experimental establishments capable of dealing with questions of a general nature relating to resistance and propulsion were added to the equipment of some of our universities and colleges. Engineering laboratories have been multiplied, but there is as yet no example of a model experimental tank devoted to instruction and research.

It is impossible here to attempt any account of Froude's " scale of comparison " between ships and models at " corresponding speeds." But it may be of interest to give a few illustrations of the working of this method, in the form of a contrast between a destroyer of 300 tons, 212 feet long, capable of steaming 30 knots an hour, and a vessel of similar form enlarged to 765 feet in length and 14,100 tons. The ratio of dimensions is here about 3.61:1, the ratio of displacements is 47:1, and the ratio of corresponding speeds is 1.9:1. To 12 knots in the small vessel would correspond 22.8 knots in the large vessel, and the resistance experienced by the large vessel at 22.8 knots,—neglecting a correction for friction,—should be forty-seven times that of the small vessel at 12 knots. By experiment this resistance for the small vessel was found to be 1.8 ton. Hence, for the large vessel at 22.8 knots, the resistance should be 84.6 tons. This would correspond to an " effective horse-power " of over 13,000, or to about 26,000 indicated horse-power. The frictional correction would reduce this to about 25,000 horse-power, or about 1.8 horse-power per ton. Now, turning to the destroyer, it is found experimentally that at 22.8 knots she experiences a resistance of about eleven tons, corresponding to an effective horse-power of over 1700 horse-power and an indicated horse-power of about 3000 horse-power; say, 10 horse-power per ton, or nearly five and a half times the power per ton required in the larger vessel. This illustrates the economy of propulsion arising from increased dimensions.

Applying the same process to a speed of 30 knots in the large ship, the corresponding speed in the small ship is 15.8 knots. Her resistance at that speed is experimentally determined to be 3.5 tons, and the resistance of the large ship at 30 knots, neglecting frictional correction, is about 165 tons. The effective horse-power of the large ship at 30 knots is, therefore, about 34,000 horse-power, corresponding to 68,000 horse-power indicated. Allowing for the frictional correction, this would drop to about 62,000 horse-power, or 4.4 horse-power per ton. For the destroyer at 30 knots the resistance is about 17½ tons; the effective horse-power is 3600 horse-power, and the indicated horse-power about 6000 horse-power, or 20 horse-power per ton,—nearly five times as great as the corresponding power for the large ship. But while the destroyer under her trial conditions actually reaches 30 knots, it is certain that in the large ship neither weight nor space could be found for machinery and boilers of the power required for 30 knots, and of the types usually adopted in large cruisers, in association with an adequate supply of fuel. The explanation of the methods by which the high speed is reached in the destroyer has already been given. Her propelling apparatus is about one-fourth as heavy in relation to its maximum power, and her load is only about one-third as great in relation to the displacement, when compared with the corresponding features in the cruiser.

The earlier theories of resistance assumed that the resistance experienced by ships varied as the square of the speed. We now know that the frictional resistances of clean-painted surfaces of considerable length vary as the 1.83 power of the speed. This seems

a small difference, but it is sensible in its effects, causing a reduction of 32 per cent. at 10 knots, nearly 40 per cent. at 20 knots, and 42 per cent. at 25 knots. On the other hand, it is now known that the laws of variation of the residual or wave-making resistance may depart very widely from the law of the square of the speed, and it may be interesting to trace for the typical destroyers how the resistance actually varies. Take, first, the total resistance. Up to 11 knots it varies nearly as the square of the speed; at 16 knots it has reached the cube: from 18 to 20 knots it varies as the 3.3 power. Then the index begins to diminish; at 22 knots it is 2.7; at 25 knots it has fallen to the square; and from there to 30 knots it varies practically as does the frictional resistance. The residual resistance varies as the square of the speed up to 11 knots; as the cube, at 12½ to 13 knots; as the fourth power, about 14½ knots; and at a higher rate than the fifth power at 18 knots. Then the index begins to fall, reaching the square at 24 knots, and falling still lower at higher speeds. It will be seen, therefore, that when this small vessel has been driven up to 24 or 25 knots by a large relative expenditure of power, further increments of speed are obtained with less proportionate additions to the power.

Passing from the destroyer to the cruiser of similar form but of 14,100 tons, and once more applying the scale of comparison, it will be seen that to 25 knots in the destroyer corresponds a speed of 47½ knots in the large vessel. In other words, the cruiser would not reach the condition where further increments of speed are obtained with comparatively moderate additions of power until she exceeded 47 knots, which is an impossible speed for such a vessel under existing conditions. The highest speeds that could be reached by the cruiser with propelling apparatus of the lightest type yet fitted in large seagoing ships would correspond to speeds in the destroyer, for which the resistance is varying as the highest power of the speed.

These are suggestive facts. Frictional resistance, as is well known, is a most important matter in all classes of ships and at all speeds. Even in the typical destroyer this is so. At 12 knots the friction, with clean-painted bottom, represents 80 per cent. of the total resistance; at 16 knots 70 per cent.; at 20 knots a little less than 50 per cent.; and at 30 knots 45 per cent. If the coefficient of friction were doubled, and the maximum power developed with equal efficiency, a loss of speed of fully 4 knots would result. In the cruiser of similar form the friction represents 90 per cent. at 12 knots, 85 per cent. at 16 knots, nearly 80 per cent. at 20 knots, and over 70 per cent. at 23 knots. If the coefficient of friction were doubled at 23 knots, and the corresponding power developed with equal efficiency, the loss of speed would approximate to 4 knots. These illustrations only confirm general experience that clean bottoms are essential to economical propulsion and the maintenance of speed, and that frequent docking is necessary in vessels with bare iron or steel skins which foul in a comparatively short time.

POSSIBILITIES OF FURTHER INCREASE IN SPEED

From the facts above mentioned it is obvious that the increase in speed which has been effected is the result of many improvements, and has been accompanied by large additions to size, engine power, and cost. These facts do not discourage the inventor, who finds a favourite field of operation in schemes for attaining speeds of 50 to 60 knots at sea in vessels of moderate size. Sometimes the key to this remarkable advance is found in devices for reducing surface friction by the use of wonderful lubricants to be applied to the wetted surfaces of ships, or by interposing a layer of air between the skins of ships and the surrounding water, or other departures from ordinary practice. If these gentlemen would "condescend to figures" their estimates or guesses would be less sanguine. In many cases the proposals made would fail to produce any sensible reduction in resistance; in others it would increase resistance.

Other proposals rest upon the idea that resistance may be largely reduced by adopting novel forms, departing widely from ordinary ship shapes. Very often small-scale experiments, made in an unscientific and inaccurate manner, are adduced as proofs of the advantages claimed. In other instances mere assertion is thought sufficient. Ordinarily no regard is had to other considerations, such as internal capacity, structural weight and strength, stability, and seaworthiness. Most of these proposals do not merit serious consideration. Any which seem worth investigation can be dealt with simply and effectively by the method of model experiments. A striking example of this method will be found in the usual form of a parliamentary paper,—No. 313, of 1873,—containing a report made by Mr. William Froude to the Admiralty. Those interested in the subject will find therein much matter of special interest in connection with the conditions attending abnormally high speeds. It must suffice now to say that ship-shaped forms are not likely to be superseded at present.

The most prolific inventions are those connected with supposed improvements in propellers. One constantly meets with schemes guaranteed by the proposers to give largely increased efficiency and corresponding additions to speed. Variations in the numbers and forms of screws or paddles, the use of jets of water or air expelled by special apparatus through suitable openings, the employment of explosives, imitations of the fins of fishes, and numberless other departures from established practice, are constantly being proposed. As a rule, the "inventors" have no intimate knowledge of the subject they treat, which is confessedly one of great difficulty. When experiements are adduced in support of proposals they are almost always found to be inconclusive and inaccurate. More or less mathematical demonstrations find favour with other inventors, but they are not more satisfactory than the experiments. An air of great precision commonly pervades the statements made as to possible increase in efficiency or speed. I have known cases where probable speeds with novel propellers have been estimated,—or guessed,—to the third place of decimals.

In one instance a trial was made with the new propeller, with the result that, instead of a gain in efficiency, there was a serious loss of speed. Very few of the proposals made have merit enough to be subjected to trial. None of them can possibly give the benefits claimed. It need hardly be added that, in speaking thus of so-called "inventors," there is no suggestion that improvement has reached its limit, or that further discovery is not to be made. On the contrary, in regard to the forms of ships and propellers, continuous investigntion is proceeding, and successive advances are being made. From the nature of the case, however, the difficulties to be surmounted increase as speeds rise; and a thorough mastery of the past history and present condition of the problems of steamship design and propulsion is required as a preparation for fruitful work in the nature of further advance.

It would be idle to attempt any predictions as to the characteristic features of ocean navigation sixty years hence. Radical changes may well be made within that period. Confining attention to the immediate future, it seems probable that the lines of advance which I have endeavoured to indicate will remain in use. Further reductions may be anticipated in the weight of propelling apparatus and fuel in proportion to the power developed; further savings in the weight of the hulls, arising from the use of stronger materials and improved structural arrangements, improvements in form, and enlargement in dimensions. If greater draughts of water can be made possible, so much the better for carrying power and speed. For merchant vessels commercial considerations must govern the final decision; for warships the needs of naval warfare will prevail.

It is certain that scientific methods of procedure and the use of model experiments on ships and propellers will become of increased importance. Already avenues for further progress are being opened. For example, the use of water-

tube boilers in recent cruisers and battleships of the Royal Navy has resulted in saving one-third of the weight necessary with cylindrical boilers of the ordinary type to obtain the same power, with natural draught in the stokeholds. Differences of opinion prevail as to the policy of adopting particular types of water-tube boilers; but the weight of opinion is distinctly in favour of some type of water-tube boiler in association with the high steam pressures now in use. Greater safety, quicker steam raising, and other advantages as well as economy of weight can thus be secured. Some types of water-tube boilers would give greater saving in weight than the particular type used in the foregoing comparison with cylindrical boilers. Differences of opinion prevail also as to the upper limit of steam pressure which can with advantage be used, taking into account all the conditions in both engines and boilers. From the nature of the case, increases in pressure beyond the 160 pounds to 180 pounds per square inch commonly reached with cylindrical boilers cannot have anything like the same effect upon economy of fuel as the corresponding increases have had, starting from a lower pressure. Some authorities do not favour any excess above 250 pounds per square inch on the boilers, others would go as high as 300 pounds, and some still higher.

Passing to the engine-rooms, the use of higher steam pressures and greater rates of revolution may, and probably will, produce reductions in weight compared with power. The use of stronger materials, improved designs, better balance of the moving parts, and close attention to details have tended in the same direction without sacrifice of strength. Necessarily there must be a sufficient margin to secure both strength and endurance in the motive power of steamships. Existing arrangements are the outgrowth of large experience, and new departures must be carefully scrutinised. The use of rotary engines, of which Mr. Parsons' turbo-motor is the leading example at present, gives the prospect of still further economies of weight. Mr. Parsons is disposed to think that he could about halve the weights now required for the engines, shafting and propellers of an Atlantic liner, while securing proper strength and durability. If this could be done in association with the use of water-tube boilers it would effect a revolution in the design of this class of vessel, permitting higher speeds to be reached without exceeding the dimensions of existing ships. It does not appear probable that, with coal as the fuel, water-tube boilers will surpass in economy the cylindrical boilers now in use; and skilled stoking seems essential if water-tube boilers are to be equal to the other type in rate of coal consumption. The general principle holds good that as more perfect mechanical appliances are introduced, so more skilled and disciplined management is required in order that the full benefits may be obtained. In all steamship performance the "human factor" is of great importance, but its importance increases as the appliances become more complex. In engine-rooms the fact has been recognised and the want met. There is no reason why it should not be similarly dealt with in the boiler-rooms.

Liquid fuel is already substituted for coal in many steamships. When sufficient quantities can be obtained, it has many obvious advantages over coal, reducing greatly manual labour in embarking supplies, conveying it to the boilers, and using it as fuel. Possibly its advocates have claimed for it greater economical advantages over coal than can be supported by the results of extended experiment. Even if the saving in weight for equal evaporation is put as low as 30 per cent. of the corresponding weight of coal, it would amount to 1000 tons on a first-class Atlantic liner. This saving might be utilised in greater power and higher speed, or in increased load. There would be a substantial saving on the stokehold staff. At present it does not appear that adequate supplies of liquid fuel are available. Competent authorities here and abroad are giving attention to this question, and to the development of supplies. If the want can be met at prices justifying the use

of liquid fuel, there will undoubtedly be a movement in that direction.

Stronger materials for the construc tion of hulls are already available. They are, however, as yet but little used, except for special classes of vessels. Mild steel has taken the place of iron, and effected considerable savings of weight. Alloys of steel with nickel and other metals are now made, which gives strength and rigidity much superior to mild steel, in association with ample ductility. For destroyers and torpedo-boats this stronger material is now largely used. It has also been adopted for certain important parts of the structures of recent ships in the Royal Navy. Of course, the stronger material is more costly, but its use enables sensible economies of weight to be made. It has been estimated, for example, that in an Atlantic liner of 20 knots average speed about 1000 tons could be saved by using nickel steel instead of mild steel. This saving would suffice to raise the average speed more than a knot, without varying the dimensions of the ship. Alloys of aluminium have also been used for the hulls or portions of the hulls of yachts, torpedo-boats, and small vessels. Considerable savings in weight have thus been effected. On the other hand, these alloys have been seriously corroded when exposed to the action of sea water, and on that account are not likely to be extensively used. Other alloys will probably be found which will be free from this defect, and yet unite lightness with strength to a remarkable degree. Other examples might be given of the fact that the metallurgist has by no means exhausted his resources, and that the shipbuilder may look to him for continued help in the struggle to reduce the weights of floating structures.

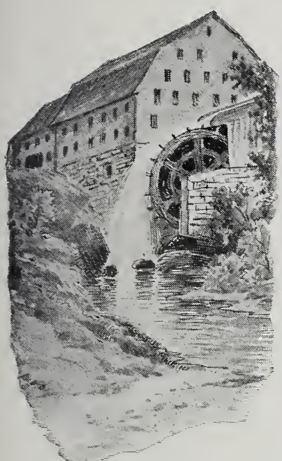
It is unnecessary to amplify what has already been said as to possible increase in the efficiency and types of propellers. With limited draught, as speeds increase and greater powers have to be utilised, multiple propellers will probably come into use. Mr. Parsons has shown how such problems may be dealt with; and other investigators have done valuable work in the same direction. In view of what has happened, and is still happening, it is practically certain that the dimensions of steamships have not yet attained a maximum. Thanks to mechanical appliances, the largest ships built, or to be built, can be readily steered and worked. In this particular difficulties have diminished in recent years notwithstanding the great growth in dimensions. Increase in length and weight favour the better maintenance of speed at sea. The tendency, therefore, will be to even greater regularity of service than at present. Quicker passages will to some extent diminish risks, and the chance of breakdown will be lessened if multiple propellers are used. Even now, with twin screws, the risk of total breakdown is extremely small.

Whatever may be the size and power of steamships there must come times at sea when they must slow down and wait for better weather. But the larger and longer the vessel, the fewer will be the occasions when this precaution need be exercised. It must never be forgotten that as ships grow in size, speed, and cost, so the responsibilities of those in charge increase. The captain of a modern steamship needs remarkable qualities to perform his multifarious duties efficiently. The chief engineer must have great powers of organisation, as well as good technical knowledge, to control and utilise most advantageously the men and machinery in his charge. Apart from the ceaseless care, watchfulness, and skill of officers and men, the finest ships and most perfect machinery are of little avail.

The "human factor" is often forgotten, but is all-important. Let us hope that in the future, as in the past, as responsibilities increase so will the men be found to bear them!

MASONRY DAMS

By Robert S. Ball, Jun., B. Sc.



THE art of the civil engineer has perhaps the highest value in the development and colonisation of new countries. No material progress can be effected without the man whose skill lies in harnessing the offerings of nature to the chariot of practical utility. He must always be in the vanguard of the pioneer, and the future industrial welfare of a primitive community ests largely with him. If nature is kind and the material resources of the country are abundant, his work may be light, but, as is often the case, he is compelled to start with very poor materials and out of them to create a high type of civilisation. But as a skilled workman can turn out good work with inferior tools, so a skilled engineer can utilise indifferent means to his ends.

The great work now begun in Egypt can be cited as a striking example of the resources of the profession to-day. A railway has already opened up a vast though unfertile territory along the banks of the Nile. As a necessary consequence of this the desolate country through which it passes will be improved and rendered fertile by artificial means, and as the Nile since the time of the Pharaohs has been used for irrigating purposes it was only natural that we should turn to it for assistance now. Vast territories have been reclaimed by this means, but there is already too much water passing Cairo which could be applied to the useful purpose of promoting the growth of crops.

To divert this water, therefore, from the natural course, and by canals and artificial channels distribute it over an extensive territory was the problem to be undertaken. This could have been accomplished by pumping, but the size of the plant necessary would render such a plan prohibitive when a much better one naturally presented itself. This other plan, now being carried into effect, consists essentially in the construction of a dam extending from one side of the river to the other, by which the water will be impounded and the level raised, thus making large pumping machinery unnecessary.

A barrage or dam is to many people a very uninteresting and prosaic construction. The word usually recalls to most of us memories of an old mill with a wooden moss-covered water-wheel, slowly turning with creak and groan. The water for the mill comes from the mill-pond, and, after doing the useful work, passes out into the stream below. The pond in most cases was not always there as we might suppose, for we see no evidences of the handiwork of man, except the mill and the old wheel with the chute for the water. The dam is often hidden by the water passing over it, and we go by without a thought as to its origin or utility. If we ever stopped to examine it carefully, we would find it to be made possibly of stones of all sizes, piled up and bound together with lime mortar. Sometimes we would find, instead of this construction, pine logs spiked together and prevented from being carried down stream by long, upright posts of the same material driven firmly into the bed of the river. Or we might see a masonry wall, the carefully cut stones of which presented a finished appearance when contrasted with the ruder, but often more picturesque types. The same result,

THE DAM ON LAKE VYRNWY FOR THE WATER SUPPLY OF LIVERPOOL

however, is attained in every case, and the water, no longer allowed to flow freely down the stream, is stored in the large reservoir or pond which has for its boundaries the banks of the stream and the dam. Though the water is thus held back, it is generally the case that the same amount passes the dam as if there were no such artificial barrier in the way, and the dam merely serves the purpose of storing the energy of the stream as a tank collects the rainwater from a roof, to be used as need requires.

Besides the important and extensive use of dams for water power purposes, they are often indispensable as a means of collecting water for the supply of towns, municipalities, and industrial centres. These structures sometimes embody the highest engineering skill, as the necessity for elaborate and efficient waterworks grows apace with the increase of population in centres which formerly were supplied by wells or small streams.

The general principles underlying the design of dams can be found in elementary hydrostatics. Water at rest is dealt with, and only in special and rare cases is it necessary to take into account the pressure of running water. If an obstruction be placed in a current of water it will be acted upon by a pressure due to the velocity of the stream. Thus, a boat anchored in a current exerts a pull on the cable due to the impact of the water on the submerged surface of the hull, the pressure varying with the velocity of the water, according to an established law. It is not, however, this pressure which we have to guard against in determining the stability of a dam. If, instead of a boat anchored in midstream, we consider the force exerted by the water on a wall, thrown across the stream from bank to bank, over which the water flows, we find that the force tending to carry it along with the current is that due to the hydrostatic pressure acting on the up-stream side. This resultant pressure is caused by the differences in elevation of the water level above and below the dam, but in most practical cases, especially in large dams, there is no water on the down-stream side, so that the structure must be proportioned to withstand the pressure of the dead weight of the impounded water alone.

The height to which the dam shall be made is governed by local conditions. When the river banks are precipitous and the stream flows through a narrow gorge, a greater height can be allowed than in cases where the banks above the dam are flat. This applies to waterworks and water power dams, but in the case of irrigating works, where the inundation of the land is the object sought, this restriction to the height would not enter. The effect of a dam is to raise the level of the water for some distance up the river, sometimes causing trouble to owners of property above. A case involving a law-suit arose on a Kentucky river, in the United States, of a man who built a dam to operate his mill by water power, and in so doing he raised the level of the water above the dam to such an extent as to interfere with the proper working of his neighbour's mill up stream.

The effective head of water for driving water-wheels is the difference between the water level above and below a dam, and as that below the upper dam was raised in consequence the structure down stream, sufficient grounds for a suit for damages were found. The defendant down stream contended that he was not infringing on the riparian rights of any one, and the evidence he brought forward consisted of statements made by a civil engineer who was engaged on the work. This man had run lines of levels before and after the construction of the dam, and the difference was not enough to justify his claim for damages.

It becomes a very complicated hydraulic problem to properly fix the responsibility in such cases, and unless accurate lines of levels have been taken before and after the dam has been built, which, by comparison at the same stage of the river, will show the effect, it is impossible to determine with any degree of accuracy how far a mill up stream would be affected. The fore-

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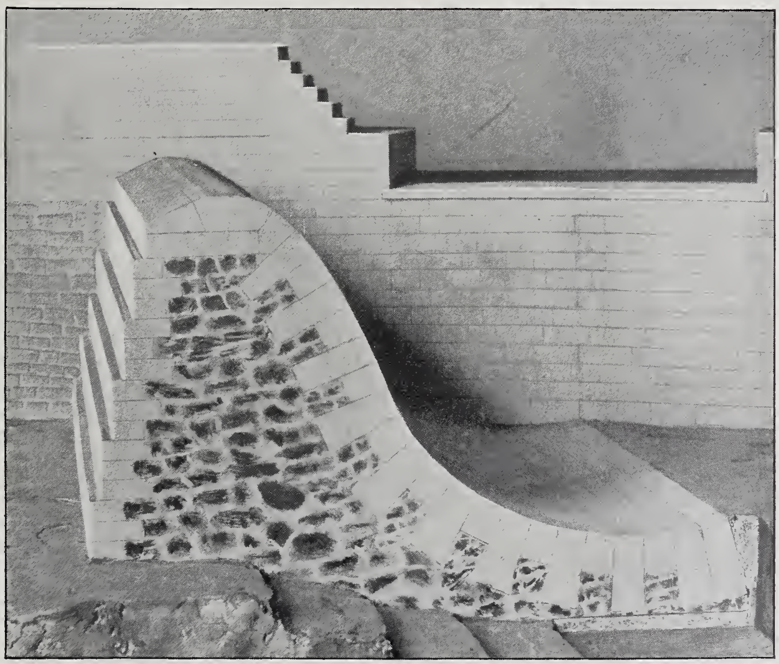
THE STRAINING TOWER ON LAKE VYRNWY

going considerations determining the height of the dam may, however, be neglected often and the final decision arrived at by the relation between the water supply and consumption. If the demand for water becomes large at any time throughout the year, as for a town in midsummer, it may be deemed expedient to erect a very high structure, sufficient to catch all the water of the preceding winter or rainy season, so that none shall escape except through the outlets or intakes designed for distributing the supply. If, on the contrary, the demand at any time of drought is only equal to, or less than, the available supply, the height of the dam will be arrived at according to the hydrostatic pressure required in the mains throughout the centre of distribution.

The height of the dam being once established, the subsequent steps in determining the outline of the structure are more amenable to fixed rules and mathematical calculation. The unit weight of water, as far as the engineer

is concerned, does not vary over the earth's surface, and, unlike many recurring problems in design, all designers have before them the same data from which to work, and the same pressures to be looked out for in proportioning the structure. Even with dams of the same height, however, great variations in outline can be seen on existing examples. Such differences are due to various constructive reasons. The material of which the dam is composed influences the width at different elevations according to its capacity of preventing the leakage of water,—an important consideration where the supply is variable or insufficient at any time.

The application of theoretical principles in designing the outline has for



FROM A SECTIONAL MODEL OF THE DAM OF THE HOLYOKE WATER POWER COMPANY, AT HOLYOKE, MASS., U. S. A.

its chief aim the guidance of the engineer in fixing minimum sections beyond which it would be unsafe to go. The actual cross-section is always more than theory would establish, and in many of the important dams throughout the world seemingly no attempt has been made to follow a form even distantly approaching the theoretical curve. It is not the writer's intention to enter here into a discussion of the various empirical and inferential formulæ which are urged by their promoters as giving the best results. The practical engineer is bewildered by the great number that have been put forward, and, finding it all too confusing, strikes a compromise which seems to him to best suit his special case. In this the real skill of the engineer lies,—to select that which best suits the special conditions of his problem out of a mass of different formulæ and even contradictory theories.

The greater number of large dams, as before mentioned, are acted upon by the water pressure on one side only. In cases where the water rises on the down-stream side the pressure is uniform which acts down-stream from the bottom of the dam up to the height of the down-stream water level. This pressure

is that due to a head of water equal to the difference between the levels on both sides of the dam.

Cases of this kind are not common, and it is customary to consider the structure under the influence of the head pf water on the up-stream side which produces a uniformly varying pressure from top to bottom. At the water level the pressure is zero and therefore we could satisfy theory by having a thin filament of masonry at that point, but oractical considerations step in and oblige us to employ a substantial thickness, thus allowing a chance for the display of judgment on the part of the engineer. Sometimes the dam carries a roadway, or approaches to gates may call for a pathway, or, as in the case of the great Vyrnwy dam which supplies the water for Liverpool, the overflow, passing over the crest, necessitates a substantial thickness at the top. This dam was the first high structure to act as a weir for the waste water, which necessitated further modifications of the profile of the outer face. It was deemed unadvisable to allow the escaping water to fall on the foundations on the down-stream side, and the outline was therefore designed with a view to minimise the deleterious effect of such a large volume of water falling many feet.

Sometimes the width at the top is larger than the height of the dam would call for,—a wise provision introduced in cases where future demand for water would necessitate an addition to the height of the structure. The celebrated Tansa dam of the Bombay waterworks, which holds back the waters of the Tansa River 57 miles from the city, is proportioned with a view to further increase in height. This dam has a length of 8800 feet, and, at the point where it crosses the bed of the Tansa River, rises 118 feet. Should the future growth of the city make it necessary, it can be raised to a maximum height of 135 feet.

Economy in cross-section is very largely due to the selection of a proper width of top. It should be as small as possible consistent with safety. When this dimension has been fixed there is but one other element in the data for determining the outline of the down-stream face of the dam to give the structure the desired stability. In gravity dams, so-called in contradistinction to arch dams, of which more, later, the dead weight of the masonry furnishes the force to overcome the overturning moment due to the water. The several classes of masonry differ so little in weight that no material effect is noticed in the outline derived by the assumptions of different unit densities of the material, and 165 to 185 pounds per cubic foot might be taken as a fair average for the weight of masonry used in such work. The water pressure has a double tendency to overturn the dam about the down-stream edge of the foundations and to move the entire mass on its base down stream.

If the bed of the river on which the dam rested were smooth, and if the dam were not fastened to it, the weight of the masonry alone might not be sufficient to resist this force in some cases, and the bond of the masonry to the rock foundation is called into play to offer the resistance necessary to avoid displacement. Dams are usually built with masonry in which the bond is broken so as not to offer a plane of small resistance for the shearing force to act upon.

Besides the horizontal resultant pressure of the water acting to overturn the dam, an additional tendency is sometimes met with in cases where faulty construction has allowed the water to enter the masonry. Quite apart from the mechanical action of the water on the material, which in itself would ultimately condemn the structure, the admission of water at any level involves an upward or lifting pressure on the dam due to the head above. This, too often disregarded at the outset, has been the cause of terribly destructive failures.

The minimum cross-section and outline of the outer or down-stream side of the dam having been determined by theory, care must be taken that the masonry is not unduly strained. A safe and practical limit is from 6 to 12 tons per square foot, and it is rare that the pressure on the foundations exceeds this. The theoretical outline of the

dam on the down-stream side would be a smooth curve, but as it would be difficult and costly to follow the curve in the structure, approximations are made by making each layer of masonry narrower than the one below by an amount sufficient to bring the outline as closely as possible to the curve. The inner or up-stream side has generally a slight batter, but is often made vertical.

Notwithstanding the chance for uniformity in this class of structure it is safe to say that even under the same conditions no two are alike. We find lavish expenditure of capital side by side with examples of false economy. The terrible results following the destruction of a dam ought to influence designers in adopting a section of sufficient weight to withstand all possible conditions, but it is inexpedient to increase the section without due regard to the increased stresses imposed by the extra material employed.

The construction of a dam often marks the beginning of an enterprise of doubtful financial success which deters capital, and the attempt to undertake the work with insufficient means at the disposal of the engineer leads to designs incompatible with the most approved methods. This is especially the case in the United States, where sometimes waterworks are constructed as one of the inducements offered to real estate men to assist in booming a town, or in places where a water power developed by the construction of a dam might induce manufacturers to erect mills in the vicinity.

We have seen that these dams resist the water pressure by the weight of the masonry alone, but there is yet another class built on a different principle, but the conditions under which it can be used are circumscribed.

Though the arch is a common structure, well known to every one, the principles on which it is constructed and the manner in which a load may be sustained by it without any apparent support directly underneath, are not a matter of common knowledge. In almost ail cases the loads acting are in a vertical plane. Thus in the case of the railway arch the weight of the passing train, to which must be added that of the masonry, combine to form the load to be resisted by the arch. Also in the case of a roadway bridge, the greatest possible weight of vehicles or pedestrians closely packed, added to the weight of the masonry, is taken as the imposed weight on the structure. It is a property peculiar to the arch that the load distributed over the entire structure will resolve itself into a force or thrust, which, passing through the masonry, will be finally transmitted to the piers on which the superstructure rests. This pressure on the piers is resisted by what engineers term the upward reaction, a force equal in intensity to the downward thrust, but acting upwards to preserve the equilibrium.

In the case of an inverted arch, such as may be seen spanning the floor of some tunnels or in the retaining walls of underground railways, the load on the arch consists of the reaction due to the weight of the superincumbent material acting downwards on the ends through the medium of brick or stone piers. In whatever position the arch may be placed, the load which it carries is transmitted to the ends to be resisted by unyielding piers or abutments, sometimes artificial and often natural, as where a stone arch is built into the rock at the ends of the span.

The application of the arch principle to dams is of comparatively recent date, for though some old structures have curved outlines, convex on the up-stream side, they were so made for the sake of appearance and cannot rightfully be called arch dams. The arch dam proper is virtually a masonry arch with which the pressure of the water, impounded on the convex side, takes the place of the load, but the weight of the masonry does not add to the load as in the case of the railway arch. Like the railway arch, however, the load on the arch dam is resolved into a lateral thrust transmitted to the abutments on the banks of the river. It is, however, difficult to determine with any degree of accuracy the magnitude of the reaction at the abutments, as the weight of the masonry and the adherence of the struc-

ture to the foundations introduce disturbing influences and a large part of the water thrust is absorbed in overcoming these resistances.

Considerations of cost limit the use of the arch dam to small spans. A narrow river bed bounded by steep, rocky embankments is especially adapted for this type, and engineers have not been slow to take advantage of such natural inducements in some parts of the world.

In the mountainous regions of California, where many rivers utilised for water power and water supply purposes rush down narrow gorges bounded by precipitous cliffs, the conditions are most favourable for the arch dam, and many of the boldest structures of this kind may be seen in that beautiful country. Perhaps the most famous is the Sweetwater dam, 90 feet in height and 340 feet long, a narrow wall, bending upstream in a graceful curve, the slender outlines of which cause feelings of distrust in the non-technical observer as to its competency to perform the steady and unremitting duty of holding back the waters of the river, for it has been well and truly said that an arch never sleeps, an aphorism which might be applied to arch dams where the water never fails.

But little has been said yet in regard to the material used in the construction of dams and the manner in which it is laid. This more properly belongs to the subject of masonry construction, but the necessity for a mass impervious to water calls for special adaptations in the design of the structure. For the reasons before alluded to in connection with the overturning of dams, it is highly important that water shall not be allowed to percolate through the masonry, and the closest attention must be directed to the foundations where the water pressure is greatest, to ensure that there shall be no weak spot for the water to seize any opportunity for escape. The beds of rivers consist of layers of sand or gravel, or often deep deposits of mud, overlying the rock at various depths. These would not form a suitable foundation as the water would speedily wash through and ultimately complete the destruction of the dam. An examination of the site for the proposed dam will sometimes reveal the nature of the rock stratum beneath; it may be solid rock or thin strata, with loose and unreliable material between. To satisfy doubts on this point the process of boring is resorted to, which, when properly done, never fails to disclose the exact nature of the formation.

The most approved form of apparatus used for this purpose is the diamond drill, which employs as the cutting or abrading tool black diamonds firmly set into a soft wrought iron bit. These stones are found in certain places in South America and compare favourably in hardness with the well-known brilliant. The wrought iron bit in which the stones are set and the drill rod to which it is screwed, are hollow, and as the bit is rotated it cuts its way down, leaving a solid core or sample of the material which is afterwards extracted by an ingenious core lifter. The rate of cutting depends, of course, on the material, but great skill is required on the part of the operator to keep the apparatus in adjustment and to prevent breakdowns and loss of the valuable diamonds. To regulate the pressure on the cutting bit the drill rods pass up through the hollow piston rod of a hydraulic cylinder, and the admission of water under pressure below the piston of this cylinder counteracts the weight of the rods which, in the deep holes sunk during prospecting, assumes large proportions. Water is forced down by a pump through the hollow rod to wash the cuttings up between the drill and the sides of the hole and to keep the drill cool. The drills are operated by steam, compressed air, electricity, or hand, as occasion may require or facilities compel, but for foundation boring a hand drill would usually be employed. An examination of the cores taken from a representative group of holes will settle doubts about the rock formation and indicate the depth to which it will be necessary to carry the foundation at different points across the river bed.

The selection of the materials of construction is a matter which is largely

governed by local conditions. The stone is often that which a neighbouring quarry has to offer, and the choice between hydraulic lime, natural, or Portland cement for the mortar is principally affected by the relative cost of the material delivered at the works. The desirable attainment of making a monolithic structure has led to the use of concrete for the interior of many of the large dams, and some which are constructed of rubble, composed of small stones surrounded by a strong mortar, combine the best features of the concrete, for no close distinction can be drawn between a concrete and a well-packed rubble with small stones. If the section of the dam follows the theoretical requirements and there is no additional masonry to assist in offering resistance to the water thrust, the best and strongest cement mortar, made of a rich mixture of Portland cement, would be best suited to such a case, but in practice, as before stated, the large cross-section of many dams in excess of theoretical requirements allows a reduction in the strength of the mortar and a frequent use of lime or natural cement or a weak mixture of Portland cement mortar. The masonry is usually pointed with stronger mortar than that used for the interior to prevent the entrance of water, and often the work is faced with ashlar to improve the appearance and at the same time diminish the size of the joints on the outside.

The public mind is never disposed to bestow as much praise on the engineer who has achieved a great work by the construction of a large dam, as on those whose labours have been directed into a channel which appeals to the attention of the average man. The bridge across the Niagara gorge, a mountain railway, a great ocean steamer carrying thousands of tons of freight and moving under the influence of several thousand horse-power, more often fill our minds with thoughts of engineering triumphs than the silent and forgotten dam, far up in some rocky gorge, or spanning some mighty river, storing up for our use an element necessary for our very existence. None the less, however, is credit due to the man through whose intellect such a work was conceived and by whose skill and energy it was carried out.

A CHRISTMAS MORNING MARKET IN KINGSTON'S MAIN STREET

AN ELECTRIC TRAMWAY IN THE BRITISH WEST INDIES

By H. Holgate

PROBABLY one of the most unlikely places in the world to look for anything very modern would be the British West Indies, and yet a visit to Kingston, the chief city of Jamaica, will convince one that the tide of progress has reached this old colony, and the existence of a new and first-class tramway system there shows that, even if some of the natives have no faith in the country's future prosperity, others have. The Jamaican, however, cannot forget the time, now past forever, when rum and sugar made riches very quickly, and these products, through foreign competition, aided by the chemist, now failing to yield as large profits as formerly, he has, at least for a time, been discouraged from developing the other resources of his wonderful island.

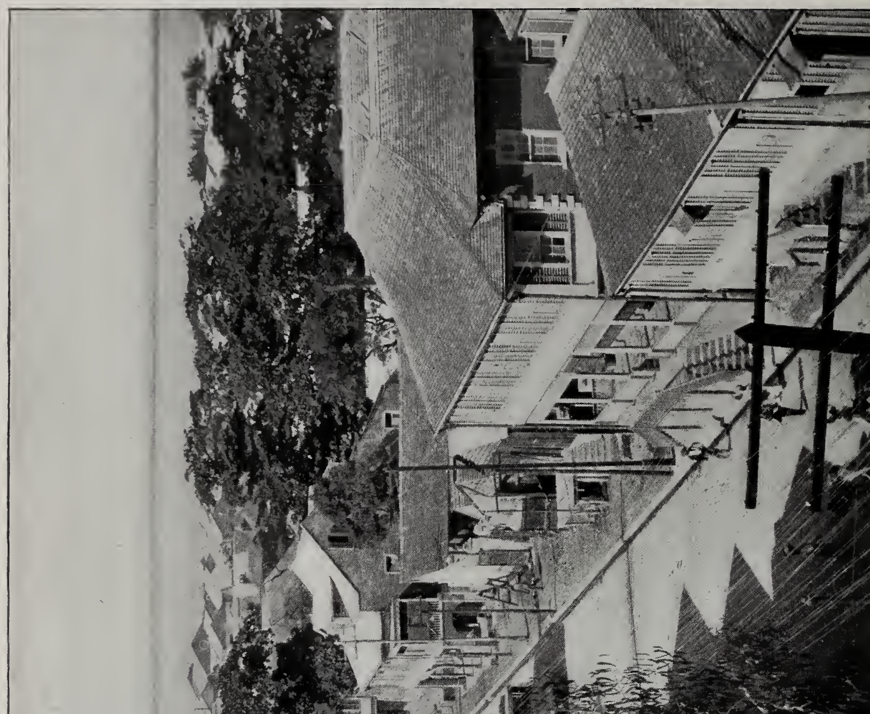
This was the condition when a Canadian syndicate, in 1897, bought the properties and rights of the Jamaica Street Car Company, and contracted to build and operate in its stead a system of electric cars. The Jamaica Street Car Company was operating about twelve miles of single-track tramways with mules, and though the business was profitable to the owners, the citizens of Kingston demanded better service than could be given by mule traction. The tramway people were unwilling to put more capital into the business, and as the government were on the eve of carrying out extensive street improvements in Kingston, whereby the street car company would be obliged to renew their tracks, the latter took the opportunity of selling the property to those who were willing to carry out the improvements.

A license was granted by the island government to the West India Electric Company to build electric tramways within the area described in the license, which embraces the whole of Kingston and a portion of the parish of St. Andrew, the population embraced in this

area being about 65,000 inhabitants. The work of the new company embraced twenty-five miles of tracks, or double the mileage of the old company, and the approved system of traction was the overhead trolley. The time for installing a new tramway system in Kingston was opportune. The streets were all in a completely worn-out condition, and during the rainy seasons the city presented a sorry spectacle. Active preparations were made by the government to reconstruct the principal streets, and the tramway tracks were laid on these ahead of the work of reconstructing the roadways. The tramway company was responsible for the building of the streets between its rails and tracks, and for 18 inches beyond the outer rails, so that in a street 32 feet wide, the company had to do most of the street construction. The surface of the roadways in the city was paved with brick, laid on a 4-inch concrete bed.

Now that the reconstruction of the principal streets of Kingston has been accomplished, the visitor of a few years ago will hardly recognise, in the clean brick streets with cast iron box drains, the old city, with its mud roads and clogged-up, filthy surface drains. The benefit produced by the change made

ALONG THE PIPE LINE



KING STREET, THE MAIN STREET OF KINGSTON, AFTER EQUIPMENT WITH TROLLEY CAR SERVICE

is a most valuable one sanitarily, and no doubt the slight visitation of yellow fever in 1897 stimulated the government to prompt action; the authorities have done their work on broad plans, and are doing it well, and yellow fever will probably never trouble Kingston again.

Within the city where brick paving was adopted the rails laid were of girder section, and weighed 92 pounds per yard; on streets where brick paving was not adopted, but where macadam was used, the track consisted of 6-inch T-rails weighing 62 pounds per yard. The tracks throughout were laid in concrete stringers on steel ties weighing 10 pounds per yard. The overhead construction is all carried by steel poles, set in concrete, and conforms to the best modern practice.

The equipment consists of twenty motor cars of the open, summer type, carrying 9 benches; six market cars, carrying 32 people and their baskets of produce; and two sprinkling tanks of 2000 gallons capacity each. The company has agreed to carry market people in special market cars at 75 per cent. of the regular fare. These cars are used as trailers; owing to the prevalence of dust on the streets, the company also runs its sprinkling cars, using fresh water for sprinkling purposes, the use of salt water being avoided for electrical reasons.

With the improved facilities for travelling, the number of passengers has increased to such an extent that additional rolling stock has already been ordered. Of course, the bulk of the passengers carried is black, and a large proportion of these are from the country, principally women who walk in with head loads of fruit, sometimes twenty miles to the tramway terminus, where they sleep over night in the " Rest House " provided by the company at a nominal charge, and complete their journey to Kingston market in the morning by electric car.

SOME OF THE CONCRETE PIERS CARRYING THE PIPE LINE

The system is divided into three districts for fares; one comprises the lines in the city; one, those north; and one, the lines east of the city. In each dis-

trict a separate collection of fares is made. The class distinction has had to be observed, and the two front benches of the motor cars are "reserved," and the fare of threepence per district is charged, whereas the ordinary fare in other parts of the cars is twopence per district.

The work of construction was commenced in Kingston in June, 1898, and the whole system was in full operation by April 1, 1899, including the power plant. The high cost of coal in Jamaica rendered the use of water power very desirable, and after making a study of the various streams within reasonable distance of Kingston, it was decided to utilise the Rio Cobre for the purpose of developing the necessary power. The river afforded a fall of fifty feet from the mouth of the railway tunnel at Bog Walk to a practicable power house site, and a dam and intake were built opposite the tunnel; the water was conducted from the intake 6200 feet down the river bank in a steel pipe, 96 inches in diameter, to the power house.

This conduit was built of one-quarter-inch medium steel plates, delivered on the ground, rolled to diameter, and punched; native labour was employed to assemble and rivet the plates. Wherever possible the pipe was embedded in the solid rock or earth; but in some places this was impossible, and the pipes had to be supported by concrete piers, three feet wide, placed eleven feet from centre to centre.

The variable load, produced by the operating of a comparatively small number of electric cars, exacted conditions of governing not usually called for, and the length of the conduit, together with its unavoidably irregular profile, added to the difficulties of governing. A steel tank, four feet in diameter, rising above the level of headwater, was erected close to the power house, and served as a relief to the water in the sudden cutting-off of load. This was found not to give sufficiently quick action. Two other tanks, each eight feet in diameter, were then erected on the pipe, one at the summit, and one between it and the power house, and these produced the results expected, overcoming the difficulties of governing the speed, and also relieving the pipe of the "breathing" action so continually going on under the constantly varying load. Had the load been steady, no difficulty would have been experienced, and the more nearly approaching a constant load, the less difficulty will be experienced in operating long pipe lines in connection with turbines. The use of heavy fly-wheels on both exciters and generators under these conditions is very desirable, as has been shown by the operation of this plant.

The power house is of most substantial construction, as it must be, situated practically in the river, and subject to the rush of water caused by the sudden freshets common to all tropical streams. The frame is of steel, and the walls are of concrete; the floor also is of concrete, carried on a steel floor system. The foundations extend to the rock, sixteen feet below the river bed.

The installation at the power house consists of two pair of 21-inch horizontal turbines, direct coupled to two three-phase, 12-pole generators of the stationary field type, operating at 550 volts, and making 400 revolutions per minute. They are of 300 K.W. nominal capacity, and were made by the General Electric Company, of New York. Room has been left for a third unit. There are two exciters, each capable of exciting three generators of the above type, and each run by a separate wheel. The generators each feed three step-up transformers, which are air-cooled. All low-tension connections are made in the air duct below the transformers, and all high-tension connections are made overhead and are led directly out of the building through an opening framed in the structure; they are carried around and again into the building to the back of the switchboard.

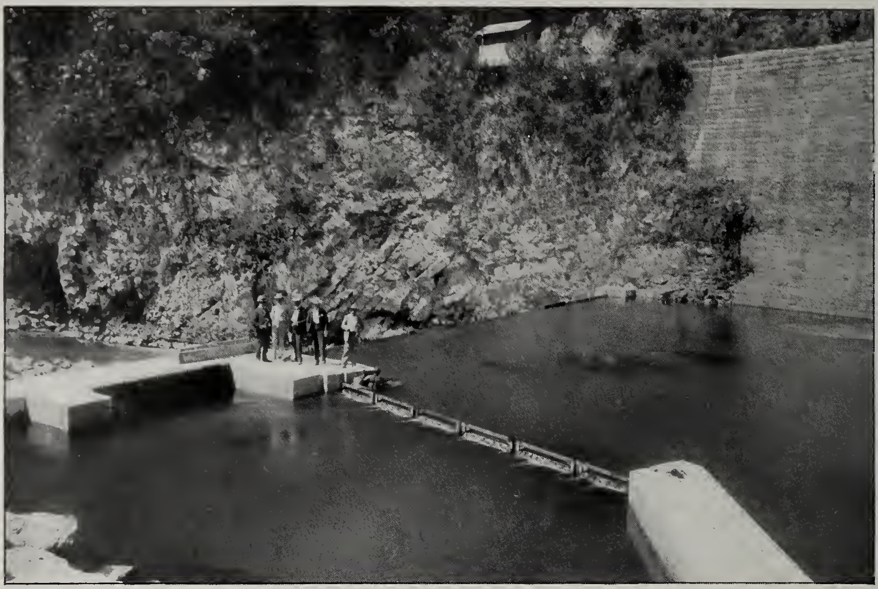
The switchboard consists of eight marble panels. The switches for breaking the high-tension current are each on a separate panel and are of the triple-pole, double-throw, oil-break form, only the handle appearing in front of the board. The two transmission lines are

ANOTHER VIEW OF THE PIPE LINE SHOWING THE CONCRETE SUPPORTING PIERS

paralleled by a triple-pole, single-throw, oil-break switch, on a separate panel. No high-tension connections are made to the front of the switchboard. The usual switching apparatus occupies the other panels, and the whole is a most complete arrangement, made with a view to the highest flexibility.

Every attention has been given to the avoidance of high-tension wires in the building, and only low-tension wires are carried in the ducts in the floor. The ratio of the step-up transformers is 1 to 26, the high-tension line voltage being 14,000. The transmission line is in duplicate. With the switchboard arrangement adopted either generator may work on either line, or either generator on both lines, or both generators on either line.

The transmission line is 21 miles long, and follows the public highway. The poles are of steel, tapered from 3½ inches to 4½ inches, and are 31 feet long; at angles, however, heavier poles are used. All poles are 5 feet in the ground and embedded in concrete. They are spaced 132 feet apart. The wires are six in number and are No. 6 gauge, of soft drawn copper, tested to 800 pounds tensile strain, without reduction in cross-section. They are carried on double-petticoat porcelain insulators, tied with No. 15 soft copper wire, and carried on locust pins on 4-inch by 6-inch pine cross-arms, secured by *U* bolts to the steel pole. The length of the line is divided equally, and the wires are transposed at each point one-third of a turn, so as to form a spiral of two complete turns in the total length. A telephone line is strung on the same cross-arms, its wires being transposed at every fifth pole; it is made of No. 15 phosphor-bronze wire strung on glass insulators, and is nearly free from induction. A system of gong signals, worked from the 550-volt circuit, is used



THE DAM COMPLETED, LOOKING DOWN STREAM

THE DAM, LOOKING UP STREAM

between stations, which remains cut in, except when it is required to use the telephone.

In order to construct this line, and to render it safe for operation, an immense amount of tree cutting had to be done, and as the tree growth is very rapid, constant trimming is necessary. A source of slight trouble arises from the "John Crows" or buzzards. These birds, after a shower, are in the habit of alighting on a cross-arm, and spreading their wings to dry, thus often coming to grief from the momentary short circuit. No serious trouble has been so caused, nor is there likely to be any, though thirteen dead birds were found in one day. Insects, too, have the bad habit of building nests in the insulators, spinning webs and shortening up the insulating surface. This, coupled with the fact that fine dust gradually gathers under the petticoats and adheres to the porcelain sides, and that the cracks in locust pins and pitch-pine cross-arms harbour dampness, render the insulation of the line a matter of great concern in times of heavy rain, and constant watchfulness is of great importance. For this purpose a patrol is organised to examine the line daily.

The step-down transformers, rotatory converters with all necessary switchboards and apparatus are placed in a brick building on the company's property in Kingston. The building is of steel construction, built-in brick walls, with steel frame roof, and clear story provided with iron louvre blades. A 5-ton travelling crane traverses the whole of the interior. There are six air-cooled step-down transformers reducing the current to 350 volts. The rotary converter units, at present two in number, are 6-pole machines of 200 K.W. capacity each. The system is complete and has been working with most satisfactory results for over six months. The wiring of the transforming station has been done with a view to having none but low-tension wires in the floor ducts. In regard to the

THE POWER HOUSE

abour used in building this work, some particulars are worth mentioning. The company brought ten white men to Jamaica to supervise the whole of the work of construction. The work was entirely new to the Jamaica negro, and he had to be taught. At first he would persist in his easy-going ways, coming to work on Tuesday and quitting Friday night, but when he found that the company kept on only good, steady hands, he fell into line and worked cheerfully the whole week.

All of the work was done by negroes,—many women being employed,—tracks laid, roads built, cars erected, wires strung, machinery installed, car house and power house built, and also the pipe line and dam. The negro is a good imitator, and when carefully shown how to do his work, will do it that way. In driving the rivets for the steel pipe it was found that just two-thirds of the day's work were done in the first half of the day, the reason being that the power of endurance was not equal to the demands of the work, and this is no doubt attributable to the quality of food used, for a baked bread fruit, and perhaps a scrap of salt fish and a mango or two, comprise the regular meal of most of the men.

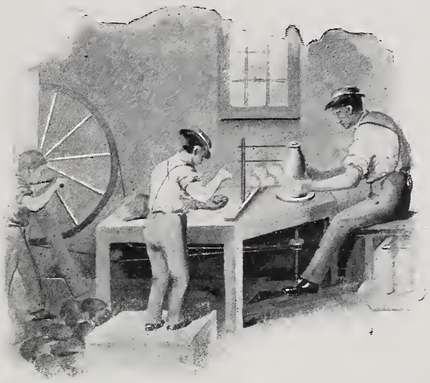
The cost of labour per unit of quantity of work done was about the same as it would be in Canada, and though the daily wages for labour were less, the amount of work accomplished was correspondingly less per man, as compared with the work done by a Canadian workman. The cost of supervision was considerably more than with white labour. The Jamaica negro is a peaceable fellow, works well under strict and kind direction, and the company's experience is that he is by no means an unsatisfactory man. The electric cars are all manned with black men, who have been trained carefully, and the extra trouble taken in their training is amply repaying the company. It has resulted in obtaining a class of men who, for general intelligence and carefulness, are equal to any men in corresponding positions elsewhere. Had the native not been such a satisfactory labourer, the company's work could not have been done in so short a time. The entire work occupied only nine months from the first breaking up of the roads to the running of electric cars.

Current Topics

As a matter of historical interest at the present time, especially in view of the prominence attained by twin-screw and triple-screw propulsion for steamships, it is worth recalling a statement recently made by Engineer-in-Chief

Melville, U. S. N., that as far back as 1862 the United States Navy had a twin-screw ship,—the *Forbes*,—and for river service during the American Civil War there were a great many multiple-screw ships, called, at the time, "tin-clads." There was also a class of twin-screw monitors built for the United States Navy in 1863, comprising four ships of something over 3000 tons, and one of these crossed the Atlantic over thirty years ago, thus establishing an early precedent for the noteworthy marine engineering achievements of recent years.

THERE can be very little doubt that the potter's wheel, or potter's lathe, as it is also termed, represents to day the most ancient form of machine tool known. Among the many sculptured records of the trades and occupations which so vividly represent the customs and habits of the ancient Egyptians, the potter and his wheel have been found frequently depicted, and it is curious to note that through the almost countless generations since that time this crude type of lathe has undergone no material modification. The primitive form was evidently a small round table, set on a pivot, and free to revolve, being turned by hand at intervals; and to this device there were added in the course of time such simple conveniences as a table to support it and a foot or a hand power turning arrangement, displaced, in recent years, in possibly a few isolated cases, by actual engine power driving. In general use, however, the potter's wheel of the present time bears all the characteristics of the one which, two thousand years, or more, ago, served to turn out pottery attesting unsurpassable taste and skill. It is curious, too, that in none of those ancient records are there shown examples of the forerunner of the common turning lathe as we know it to-day, even though the art of turning may be traced back to a very remote period. Among Egyptian antiquities that have been found at Thebes and other cities there have been many specimens which exhibited indubitable signs that the material, while in revolution, was subjected to the action of a tool held at rest,—legs of stools and chairs, for example, and lamps and musical instruments,—and in later centuries, among the Greeks and Romans,



A POTTER'S WHEEL

the lathe was undoubtedly in common use. Cicero and Pliny both refer to the art of turning, and Herodotus thus uses the lathe as a familiar simile:—" But I smile when I see many persons describing the circumference of the earth, who have no sound reason to guide them; they describe the ocean flowing round the earth, which is made circular as if by a lathe." Unfortunately, however, it appears that none of these nor other early writers have left any account of the lathes and tools employed by their contemporaries.

IN railway engineering it has become a matter of interest and of considerable importance as well to determine, at least with a fair degree of approximation, what is the most economical weight of a locomotive. In modern locomotives, as *The Engineer*, of London, put the matter in a recent article on the subject, probably everything is made very much stronger and heavier than it need be to stand the stresses to which it is submitted, the intention being to make needful repairs as few as possible. But a point can be reached beyond which additional weight does no good, and

every locomotive superintendent must settle for himself on his own lines when that point has been reached. To drag about the country several tons of unnecssary dead weight is very far from being economical. The late Mr. Stroudley held that engines should always be made as light as possible, and that to keep them out of the repair shops recourse should be had, not to increasing the weight of parts, but to excellence of workmanship and material. Others hold, however, that in the long run the heavier locomotive is the better, that the lighter engine is a more delicate machine, and that, although as good results may be got from it as from the heavy engine, they can be had only when a superior and expensive type of men have charge of it.

In the early days of Russian railways Messrs. Winans built certain locomotives for the Czar which were paid for by the pound weight, like so much tobacco or sugar. It used to be said that these engines were cast whole, and that being taken out of the sand in the foundry red hot, water was put into the boilers, and steam enough generated to run a trial trip. The jest shows what was thought of these engines. It is certain that they were enormously heavy for their power. After a time these engines were displaced by others of lighter make; but these soon succumbed to the tender mercies of Russian drivers and Russian winters, with the result that Winans' engines were put again on the road, and did admirable service for many years. In Great Britain, in the United States, and in Europe there is a large body of opinion all pronouncing in favour of the heavy locomotive; and not long since it was stated by an excellent British authority that it would be found in the long run that a locomotive engine could not be made too heavy, because a great annual mileage was the one thing needed, for the simple reason that now and for some time past every important railway in the kingdom has been short of motive power. The locomotive superintendent who can get 30,000 miles per annum out of his engines will do with two of them what the man who runs only 20,000 miles a year requires three engines to do. Notwithstanding all this, however, it is, no doubt, possible to build engines which are needlessly heavy. At what point redundancy of structure comes in is the point to determine.

It was the great fire of London, away back in the seventeenth century, so we are told in a recent issue of *Publicity*, that first made fire insurance a regular institution. The immense loss caused by this disaster opened the eyes of business men to the necessity for a remedy, and from 1669 to 1681 various schemes of insurance were laid before the Court of Common Council; but in the latter year a private company took the initiative, and the court soon abandoned the slight attempt it made to issue insurance policies. The growth and multiplication of such companies since that time, more especially during the present century, is a natural result of the increase of wealth and of public appreciation of the benefits of insurance. Centuries before there existed a most interesting form of it, and that not among any of the great commercial nations of the Middle Ages, but in a remote island of the Atlantic,—in Iceland. When the damage had been valued by the neighbours, one-half of the loss had to be borne by the yeoman himself, and the other half was made good by all the other yeomen in the district. From each of these a certain amount was levied in proportion to the value of his property, and if this were not paid within a specified time, it could be seized by law. At the same time it was provided that no one could be called upon to pay as his share more than 1 per cent. of his whole property, and it was not compulsory to compensate the same person for loss by fire more than three times. The method was, indeed, very similar to that of the first London companies, which called upon the members to pay their shares only when a fire actually occurred.

Two of the largest British railroads, the Midland and the London & North Western, have recently given out some very interesting figures relating to the cost of locomotive repairs on their lines. The Midland data are contained in an address by Mr. Samuel N. Johnson, locomotive superintendent, as president of the Institution of Mechanical Engineers, and cover a period of twenty-four years, from 1873 to 1896. The figures for the London & North Western are given in an article on the average life of a locomotive and the cost of repairs and renewals in London *Engineering*. This article contains a tabular statement giving the mileage and cost of repairs of the locomotives on the London & North Western road during a period of thirty years, from 1869 to 1898. The figures were examined and verified by the locomotive superintendent, Mr. F. W. Webb. The number of locomotives on the Midland in 1873 was 1040, and in 1896 it had increased to 2327,—an average increase of 53 engines per year, and the equipment having doubled in numbers in twenty years. The mileage made by Midland engines in 1892 was, for passenger service, 176 miles per day; merchandise freight, 128 miles; and coal and ore, 95 miles. The annual train mileage per engine in 1873 was 19,576 miles, and while it increased to 20,700 in after years, yet it was actually lower in 1896 than in 1873, being in 1896 only 18,457 miles per engine. The cost of repairs and renewals of locomotives on the Midland was, in 1873, for wages, 2.6 cents; material, 3.12 cents; total, 5.72 cents. In 1896 the cost was, wages, 2.64 cents; material, 2.64 cents; total, 5.28 cents, showing a slight decrease.

Some interesting data also are given in regard to the age and mileage to be obtained. Boilers, before worn out, will have had a second copper fire-box, and the brass tubes will be changed four or five times. The average mileage of new brass tubes is 82,400 miles, and of new copper tubes, 122,500 miles. From the record of 1000 boilers worn out and scrapped, the average life and mileage was obtained, showing the life in years to average 15, with a maximum of 25 years; and the average mileage 382,900, and maximum 655,800 miles. The record of 508 cylinders worn out shows their average life to be 12 years, and the maximum 27 years; average mileage, 319,700 miles, and maximum 692,000. For 1109 crank axles worn out the average life was 7¾ years; maximum, 24¾ years; average mileage, 191,500 miles; maximum, 634,600 miles. The weight of a representative passenger train on the Midland road is as follows:—Engine, 47 tons; tender, 38.4 tons; seven passenger cars, 170.4 tons; total, 255.8 tons.

During the eight years ended with 1880 the coal consumption, as an average for all classes of service, showed a decrease of 9.68 pounds per train mile, or about 17.2 per cent. This was effected, notwithstanding the increased loads and speeds, by revising the design of the engine, and by building locomotives of greater power, and therefore better capable of dealing with the heavier trains. After 1880 the coal consumption per train mile steadily increased, from 46 pounds to 54 pounds, or over 17 per cent., being as high in 1896 as in 1874. The percentage of passenger train miles and freight train miles during the period remained about normal. It would appear from this that the weight and speed of trains after 1880 increased more rapidly than the improvement in engines and methods of firing, for the economical showing up to that time could not be maintained. The average speed of all passenger trains was 42 miles in 1873, 45 miles in 1880, and 48.5 miles in 1896.

The locomotive statistics for the London & North Western Railway for a period of thirty years shows that the number of engines owned by that company in 1869 was 1539, and increased

to 2878 in 1898, —an average increase per year of 46. The average mileage per year per engine was 15,127 in 1869, and 16,521 in 1898, or an increase of 1395 miles, or 9 per cent. The mileage in 1871 was 16,372, or very nearly the same as that made 28 years after, showing very little progress in that particular respect. The average cost of repairs and renewals of locomotives was 2.6 cents per mile for wages, and 2.8 cents for material, a total of 5.4 cents. In 1896 the cost was 2.37 cents for wages, and 2.63 cents for material; total, 5 cents. The cost of repairs during the same year on the Midland Railway was 5.28 cents per mile. In the United States the cost of repairs to large modern locomotives is very nearly 5 cents per mile, and the average cost, including smaller engines, is probably less than 4 cents, showing that with cheaper labour and cheaper material, British locomotive repairs cost as much, if not more, than in this country. The most surprising thing to notice in these reports is the very small annual mileage made by locomotives on these two prominent British railways. On the Midland the mileage per engine per year is only 20,000, and on the London & North Western it is only 16,000 miles. In the United States the average mileage per engine per annum on most roads is double that above recorded, and on some of the large roads it is even more than that.

Of the mysterious charm of music we have convincing demonstration in the negro worker in the United States, where, in construction work on railroads, for example, a wise foreman knows that he can get about 50 per cent. more work out of his gang if he can keep them singing; then the picks and shovels will invariably keep time with the music. The same custom, said *Dixie*, not long ago, seems to prevail among the African aborigines. Building a railroad in the Soudan is not carried on to the sound of the voice of a "boss" directing a gang of labourers. As becomes the milder atmosphere of the tropics, a railroad in those regions is built to the "lascivious pleasing of a lute," or the African equivalent. The "sofas" are the working people, and the "griots" are the musical ones. The "sofas" will not work unless the "griots" play. So every gang of men has its orchestra. The "griots" play on flutes and rude harps the peculiar tunes of Africa, and the picks and shovels of the "sofas" go industriously as long as the music lasts. Let the music stop, and the work slackens and then fails altogether. So, to the sound of music the steel rails are penetrating the Congo region and forcing their way through the Soudan. To every gang of forty or fifty men there are assigned two harp players and a flute player, and as long as the music keeps up the black labourers do not seem to feel fatigue. A case somewhat similar to this is the custom in Cuban tobacco factories. In the big room where the cigarmakers work there is always a reader. He sits up on a platform and reads novels to the workmen, as they manipulate the tobacco. Again, on board ship a sailor will work as well again if he is permitted to sing a working song, the rhythm of which keeps time to his labour. But in the building of railroads music is a new factor. Cecil Rhodes' "Cairo to the Cape" road will be literally fifed and harped through Africa.

In a recent issue of the *Brazilian Bulletin* an account was given of the Ypanema Iron Works, in the State of San Paulo, Brazil, which date from 1590, in which year two Catalan forges were set up by Affonzo Sardinha. Work was carried on regularly until 1629, when it was abandoned because of the death of the owner. One hundred and thirty-one years later a new furnace was built, with leathern bellows and a trip hammer. In a short time this experiment was abandoned and the place became a sugar mill. In 1801 a blast furnace, with hand machinery to furnish the blast, was erected. It seems unnecessary to say that this gave no

results. In 1811 the government took charge and contracted with certain Swedes to erect *stückofen* and make bar iron. In 1814 four of these furnaces were in operation, but the ore proved so refractory that the yield was only one ton of iron for forty-one of charcoal, making the value of the metal only two-thirds that of the fuel. The Swedes were dismissed and blast furnaces erected with proper blast appliances, and the system now employed was gradually developed. Pig iron and bar iron are made at these works, but the quality of both is inferior, owing to the poor quality of the ore. The Brazilian Government offers the works and the mines for sale. The above-mentioned Catalan forges, adds the *Bulletin* of the American Iron and Steel Association, may or may not have been built prior to similar works in Mexico; but they were certainly the predecessors of iron works of any kind in the United States or Canada. The St. Maurice Iron Works in Canada, the first in that country, date from 1737, and the iron works at Falling creek, in Virginia, the first in the United States, date as far back as the year 1619.

HENRY MARION HOWE

A BIOGRAPHICAL SKETCH

AMONG American metallurgists Henry Marion Howe ranks foremost in the list, with few peers, if any, in the old world. He is the son of Dr. Samuel G. Howe and of Julia Ward Howe, two names which, the world over, suggest Christian charity, philanthropy, patriotism, culture, the highest moral, intellectual and civic attainments. Among his distinguished ancestors he counts a member of the Boston Tea Party and two pre-Revolutionary governors, and among his near relatives, Charlotte Corday and General Francis Marion.

He was born in Boston in 1848, graduated from Harvard College in 1869, and from the Massachusetts Institute of Technology in 1871. He then studied the manufacture of steel at the Bessemer Steel Works, at Troy, N. Y., where he learned to carry out with his own hands the more important operations connected with the making and working up of iron and steel. In 1872 he assumed the duties of superintendent of the Bessemer Steel Works at Joliet, Ill., now owned by the Illinois Steel Company. From the time he left the Massachusetts Institute of Technology until 1883 he was actively engaged in metallurgical manufacture, chiefly that of iron and steel.

In 1877 Mr. Howe undertook an important mission to Chile in connection with copper smelting, and during the period from 1880 to 1882 he designed and built the works of the Orford Nickel and Copper Company at Capelton, Canada, and at Bergen Point, N. J. From 1883 to 1897 he resided in Boston, engaged as a consulting metallurgist and an expert in metallurgical patent cases, being also a lecturer on metallurgy at the Massachusetts Institute of Technology.

In 1897 he was offered the chair of metallurgy at Columbia University at New York, which he accepted and now occupies.

At the Paris Exposition in 1889 he was a juror in the class of "Mining and Metallurgical Processes," and in 1893 he was president of the jury on "Mines and Mining" at the World's Columbian Exposition.

Professor Howe is a member of many scientific and technical societies, being a past president of the American Institute of Mining Engineers, which office he held during the International Engineering Congress which met at Chicago

in 1893. He is a member of the American Academy of Arts and Sciences, and a non-resident member of the American Philosophical Society, of Philadelphia, an honour paid only to scientists of high attainments.

His writings are too many to be enumerated here, for he has enriched metallurgical literature with about a hundred papers and memoirs, all of them valuable, some of them classical. In 1890 appeared, in book form, his treatise on "The Metallurgy of Steel," a monumental work, which called forth the admiration of the metallurgical world, and which will forever testify to the magnitude of the intellectual power of its author.

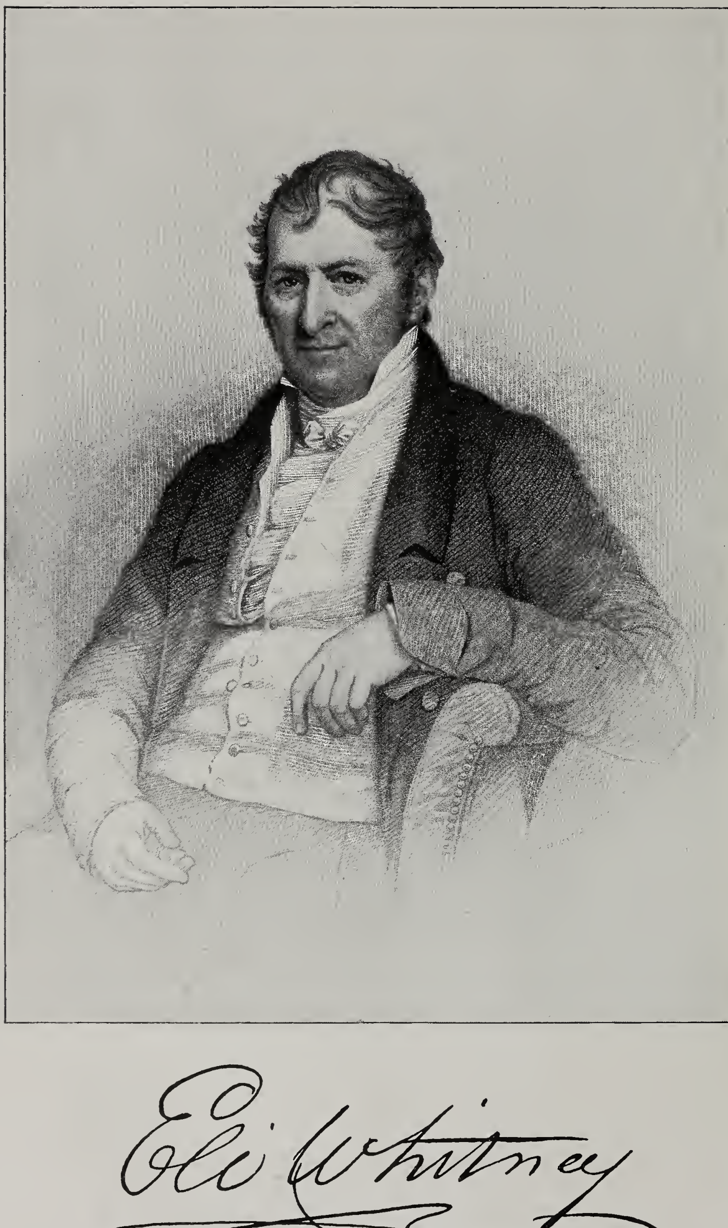
His writings, crowned by this masterly production, brought him speedy recognition by the scientific societies of the world, among which stand foremost the award of the Bessemer gold medal, —the highest distinction to which a metallurgist may aspire, and which was presented to him in 1895. The Bessemer medal was founded in 1873 by the late illustrious Sir Henry Bessemer, and has been awarded to only three other Americans,—Alexander Lyman Holley, Abram S. Hewitt and John Fritz. Professor Roberts Austen said, in part, on the occasion of the presentation of the medal to Professor Howe, that "he (Professor Howe) had done for the literature of metallurgy what his own countrymen, Emerson, Hawthorne and Lowell, had done for English literature generally,—to produce a work which might form a part of, and enter into the daily occupations of, their life."

The French "Société d'Encouragement pour l'Industrie Nationale" awarded to Professor Howe a prize of 2500 francs, on which occasion Professor Jordan, of the Paris École Centrale," said:—"Since its first appearance Professor Howe's work has commanded the close attention of experts in every country, owing to the conscientious criticism, wide scholarship, and thorough training in science of its author, as well as its industrial application. It was evident that he was theoretically versed in metallurgical chemistry and mechanics, able to avail himself of the resources of the laboratory and experimental research to the benefit of his explanations and verifications of current statements and theories; a linguist familiar with the special literature of the chief metallurgical countries of Europe, profoundly learned, and endowed with an almost incredible capacity for work; but, besides, he proved himself a practical man, an observer of details in shop and work, appreciating their significance, and abreast of the times concerning technical improvements."

The German Society for the Promotion of Industry presented to Professor Howe its gold medal, — the highest distinction which it can bestow upon a foreigner; the Franklin Institute, of Philadelphia, also presented to him its highest award, the Elliot Cresson gold medal.

It is not for the disciple to criticise the work of the master, much less the master himself; yet the writer cannot refrain from adding a word of personal admiration and gratitude to these few lines,—admiration for the mental capacity and erudition of Professor Howe, as a writer, for his clear and forcible style, his irresistible logic; for his ability of drawing light and order where others see only darkness and chaos; for that absence of all unworthy rivalry which so often blurs scientific work and discussion; for the skill of the experimenter, the acuteness of the observer, the trustworthiness of the *reconter;* gratitude for the lofty conceptions of scientific work imparted to us by his writings and by personal contact,—a conception which ought to make of scientists the most reverend of men instead of skeptics.

A. Sauveur.



THE INVENTOR OF THE COTTON GIN

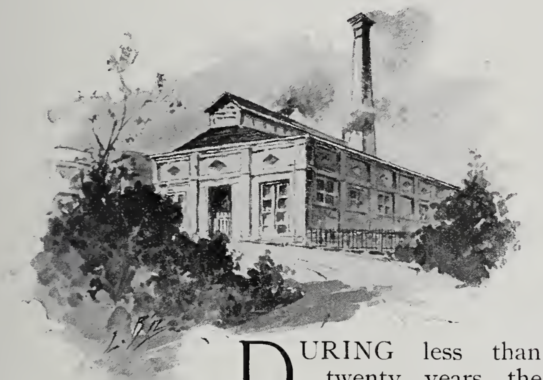
SEE PAGE 166

CASSIER'S MAGAZINE

VOL. XVII DECEMBER, 1899 No. 2

THE DEVELOPMENT OF ELECTRIC STATIONS

By Alton D. Adams

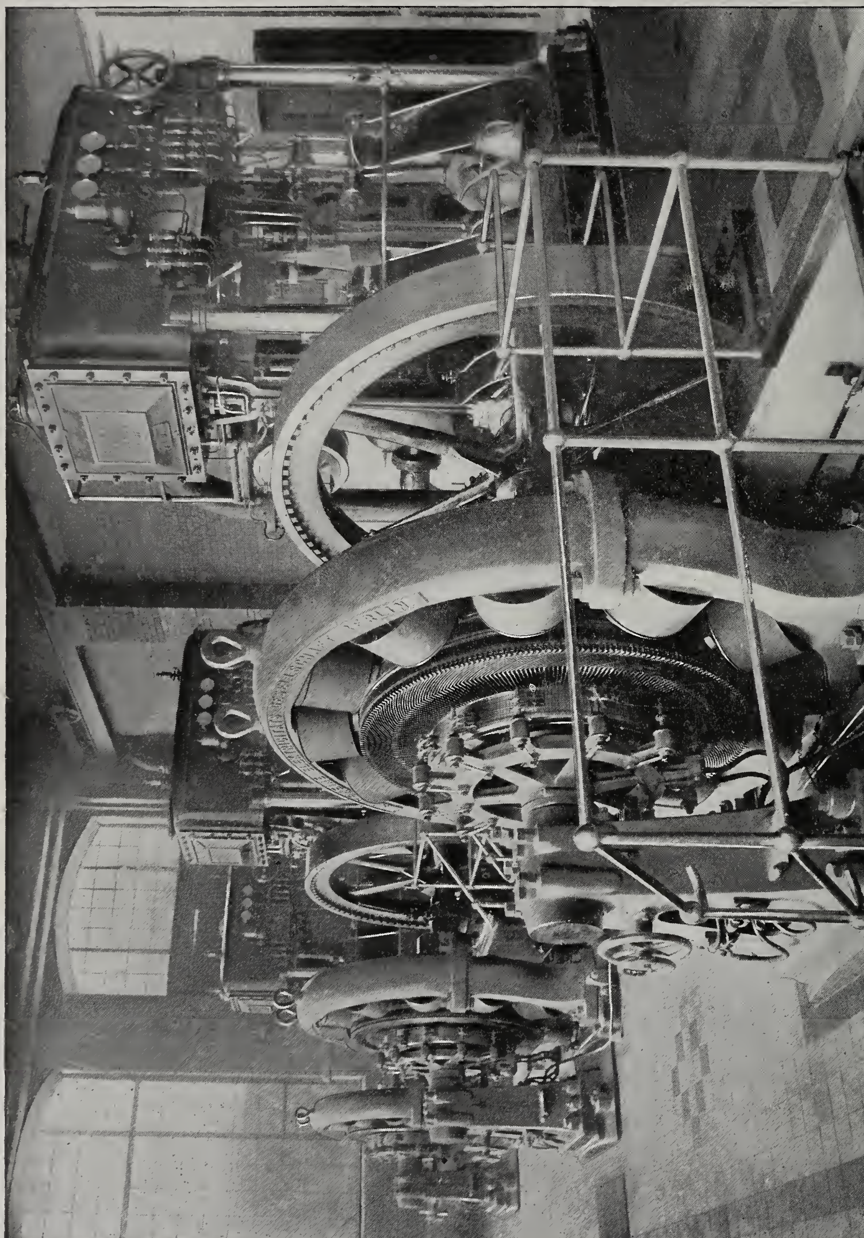


DURING less than twenty years the electric station has grown from a small machine in an out-of-the-way place to the greatest centre of power development known in history. In the early days of electrical engineering an unused corner of some factory or a convenient basement usually served to locate the first machines for public service. For some years electric energy was distributed solely as a lighting agent. At first the service was entirely for arc lamps; later came the incandescent. As the demand for light increased, chance locations became impractical and central stations, designed for the especial production of electric energy, began to appear.

Early stations were not always commendable from an engineering standpoint. A cheap wooden building, cheap boilers and piping, one or more slow-speed engines of poor regulation, a counter shaft, and the necessary dynamos belted to it made up the usual outfit. In many cases steam pipes were not covered; the engines were simple, non-condensing, operating much of the time on a small part of their rated load; the long counter shaft was a large and constant consumer of power; the feed-water heater was unused, and the economiser was unknown. Conditions outside the pioneer stations were but little more satisfactory than those within. In most cases all circuits were overhead, poles were small and not securely guyed, wires were run along the sides of buildings, contacts with tin roofs and metal corners were common, and the insulation of any particular conductor was much more a matter of hope than of knowledge.

Rapidly increasing demands for electric current made frequent additions to equipment necessary. Capital was rapidly invested, other and better stations were built. Engines of higher speed were obtained and shafting was done away with, belts being run from generators to engines direct. Feed-water heaters were adopted in most cases, compound engines in some, and economisers in a few. Steam pipes were covered, engines operated at more nearly full load by a variation in the number at work, and the coal consumption per kilowatt-hour output of electrical energy decreased by from 10 to 40 per cent.

Outside of the station better work be-

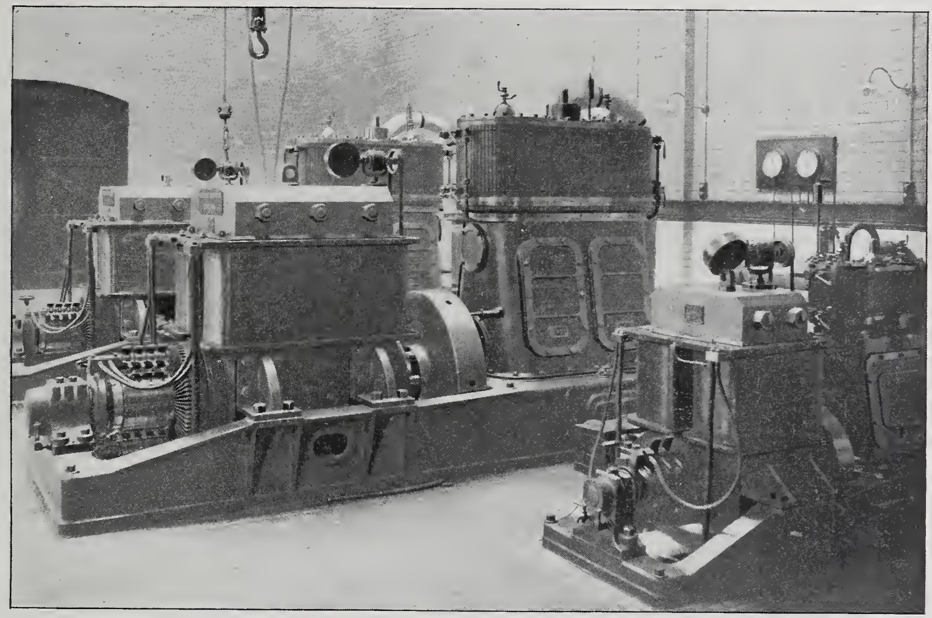


THE ELECTRIC RAILWAY POWER STATION AT DUISBURG, GERMANY. EQUIPPED BY THE ALLGEMEINE ELECTRICITÆTS GESELLSCHAFT, BERLIN

came the rule. Wires were no longer run along the sides of buildings, poles and roof fixtures grew more substantial in character. The mechanical features of overhead lines were made more secure and their insulation was made more probable. Many circuits in large cities were put underground, rendering them safer, and more reliable and permanent. Not only did the size, efficiency and capacity of individual stations increase, but also the number of stations in the same town and city. New plants were erected in sections not previously served, and to-day hardly a large town is without the electrical supply.

The stationary electric motor came into general use and proved a large factor in central station practice, especially in large cities. The incandescent lamp, at first the infant, had become the giant, and required much more equipment for its operation than the once all-important arc lamp. Special types of dynamos were developed for each great class of electric device. Arc lamps required one sort, incandescent lamps another, and stationary motors, in many cases, a third. The load intended for one dynamo could not be operated by the others, and the different dynamos could not work in multiple. Engines had sometimes to run on light loads because the kind of load to which their connected dynamos were suited was small. This condition of central station design and operation for general electric light and stationary power service is the prevailing one to-day.

Meantime, another great industry has become dependent on electric stations,—the transportation of passengers on electric roads. Fifteen years have seen the majority of existing street railways transformed into electric roads, and a separate class of electric plants has been erected to furnish power for them. These so-called power stations for tramway lines have had, from the start, one decided advantage in that all electric generators were designed to furnish current of the same kind, and could, therefore, be operated in multiple. The same experience with large and heavy shafting had, in many cases, to be gained, with an ultimate change, in most cases, to



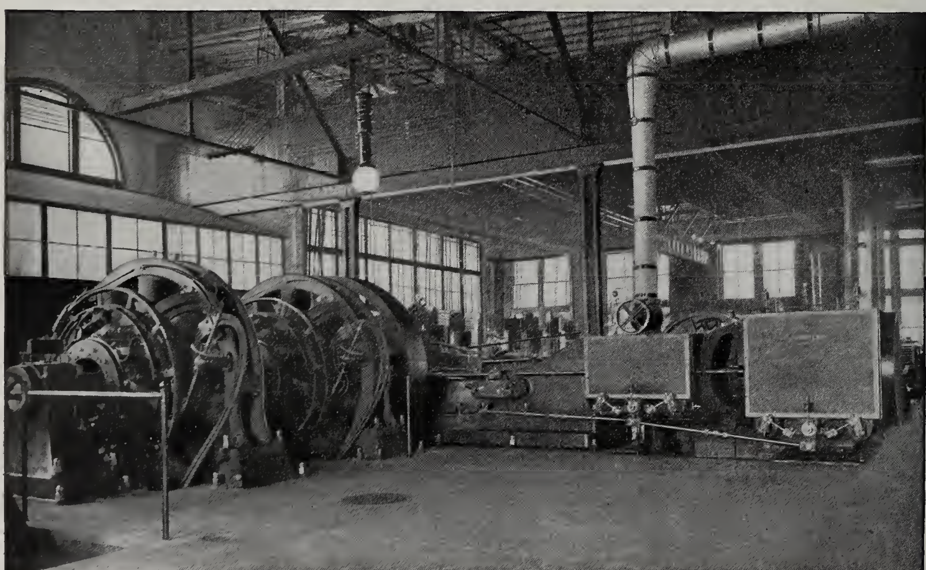
THE BURY CENTRAL STATION. EQUIPPED BY MESSRS. SIEMENS BROS. & CO., LTD., LONDON

belt or direct connection between each dynamo and its engine, as in the electric light stations. With the extension of street railway service new power stations were erected so that in the system of a single large city as many as five or six generating plants are now in use. The above hasty glance at the development of electric light and power stations shows a constant advance in their number, capacity, and equipment during the brief period of their existence, and a study of present tendencies indicates that other changes of a more sweeping character than any of those in the past have already begun.

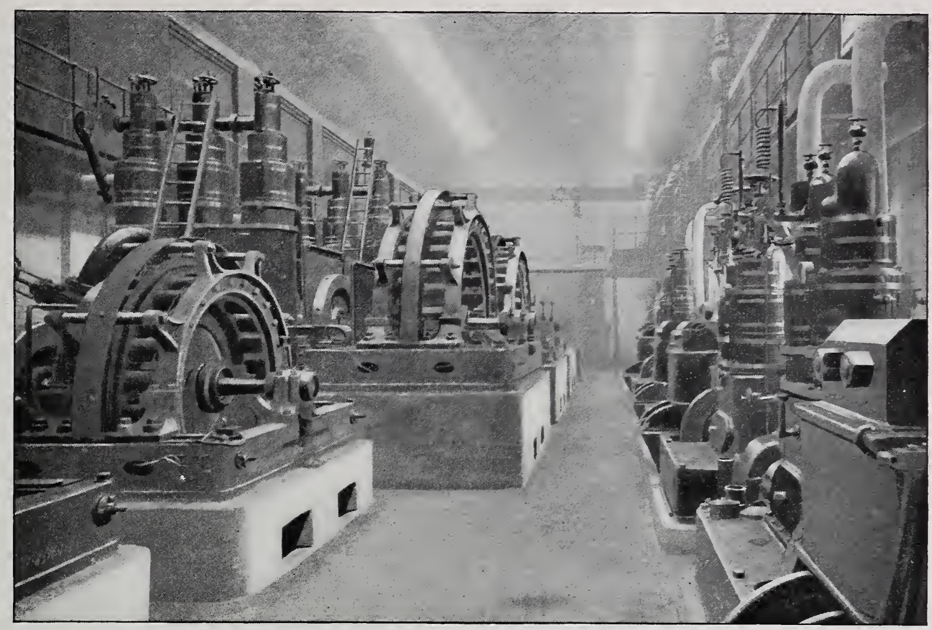
By far the greatest loss in electric stations occurs between the boiler and the engine shaft. About 80 per cent. of the heat energy from the combustion of coal enters the engine cylinder with the steam, and more than four-fifths of this escape at the exhaust. The nearer to its maximum desirable load the engine can be operated, the larger percentage of the heat energy entering its cylinder will it deliver as mechanical motion at its shaft. To get the best results from compound, triple expansion and condensing engines they must be of large capacity. To insure a nearly constant maximum load on very large engines when each is connected with but one or two generators, implies a great delivery of power from a single station, and this, in turn, makes it necessary that each station serve a large area, or at least one that requires a great amount of power.

Two conditions of electrical supply tend against large direct connected engines with full and uniform loads on each. These conditions are the various kinds of electric service required and their great change in amount during the day. The work commonly required of current from electric stations is that of arc lamps, motors, heaters and incandescent lamps. Arc lamps are most generally operated, especially for street lighting and at long distances from the station, by machines that require from thirty to one hundred horse-power each. These arc dynamos cannot, obviously, be direct connected to large economical engines, and admit of mechanical driving from such engines only through the medium of shafting.

The form or quality of electric currents supplied by arc dynamos is not



A 1000 H. P. TANDEM COMPOUND CONDENSING ENGINE. BUILT BY MESSRS. RUSSELL & CO., MASSILLON, O., U. S. A., IN AN EDISON LIGHTING STATION. DIRECT CONNECTED TO TWO 300 K. W. GENERATORS. BUILT BY THE GENERAL ELECTRIC COMPANY, NEW YORK

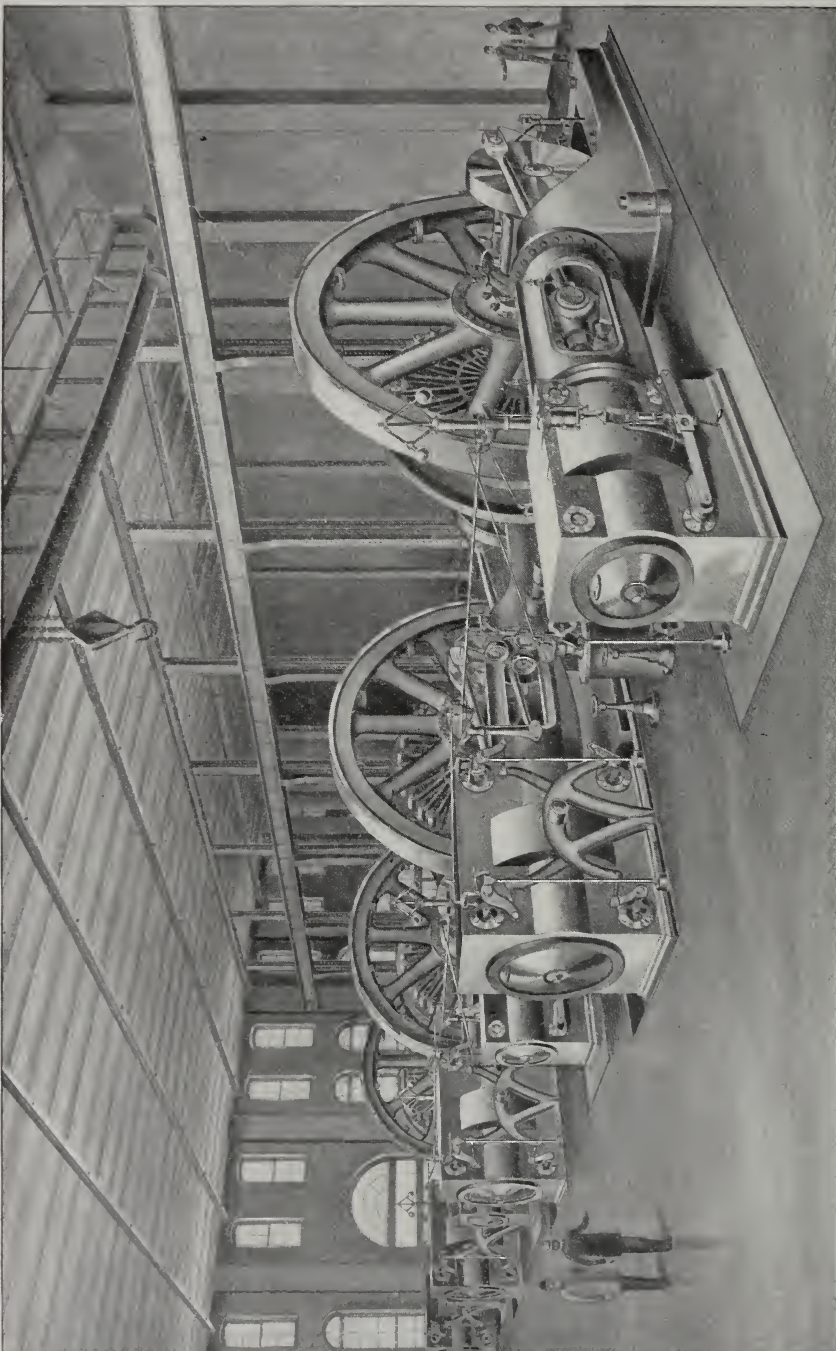


THE BRISTOL, ENGLAND, CENTRAL STATION. EQUIPPED BY MESSRS. SIEMENS BROS. & CO., LTD., LONDON. DIRECT-CONNECTED WILLANS ENGINES. BUILT BY MESSRS. WILLANS & ROBINSON, LTD., RUGBY, ENGLAND

suited for use in motors or incandescent lamps, and only to a limited extent in heaters. The load on arc dynamos and the engines devoted exclusively to their operation depends, therefore, on the number of arc lamps in use at any particular time.

Stationary electric motors which now form a large percentage of electric station loads in many cities and towns may be supplied with energy from generators as large as the amount of the service warrants. When the motors are comparatively near the station, the generators which supply them may also, in some cases, furnish current to incandescent lamps, but in the more frequent case where motors are much scattered over a considerable area, the electric energy furnished to them is not well suited to any other purpose except heating. Motor loads, while not subject to the extreme variations common with those lamps, are by no means uniform, and engines connected to generators suited for these loads alone cannot be operated at a uniform maximum capacity. Electric heaters are adapted to work with currents from either motor or incandescent lamp circuits, and tend, in a small measure, to increase the small loads in these kinds of service.

Incandescent lamps form the most important single item in central station service. They consume more energy than any of the other kinds of service, and their variation, as to rate of consumption, is greater. The station load of incandescent lamps is many times greater during one part of the day than during others, so that it is impossible to keep a number of very large engines direct connected to dynamos for this service at anywhere near their full load. The extent to which dynamos for incandescent service are able to supply arc lamps, heaters and motors tends to even up the load line for these generators, but a very large part of the latter kinds of service are beyond the reach of ordinary incandescent dynamos. Arc lamp loads are usually small during the morning and early afternoon hours, attain their maximum at about the time

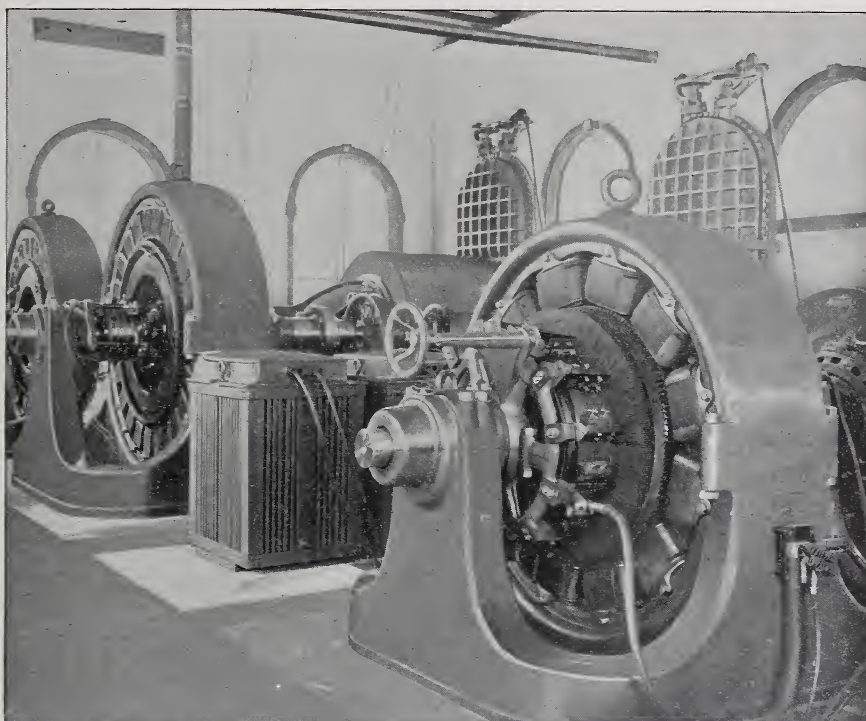


INTERIOR OF THE UNION LOOP STATION OF THE WEST CHICAGO STREET RAILWAY CO., CHICAGO, SHOWING 1600 K. W. DIRECT-CONNECTED CROSS-COMPOUND CONDENSING ENGINES. BUILT BY THE INTERNATIONAL POWER COMPANY, PROVIDENCE, R. I., U. S. A.

street lamps are lighted, then decrease gradually until midnight, after which they are nearly constant until morning.

Electric motor loads are mostly confined to the working hours of the day, and vary some in amount, according to local conditions. As the heaviest lamp loads do not usually come on until after most of the motor service is over for the day, such combination of these two loads as is possible on the same generators tends to uniform loads.

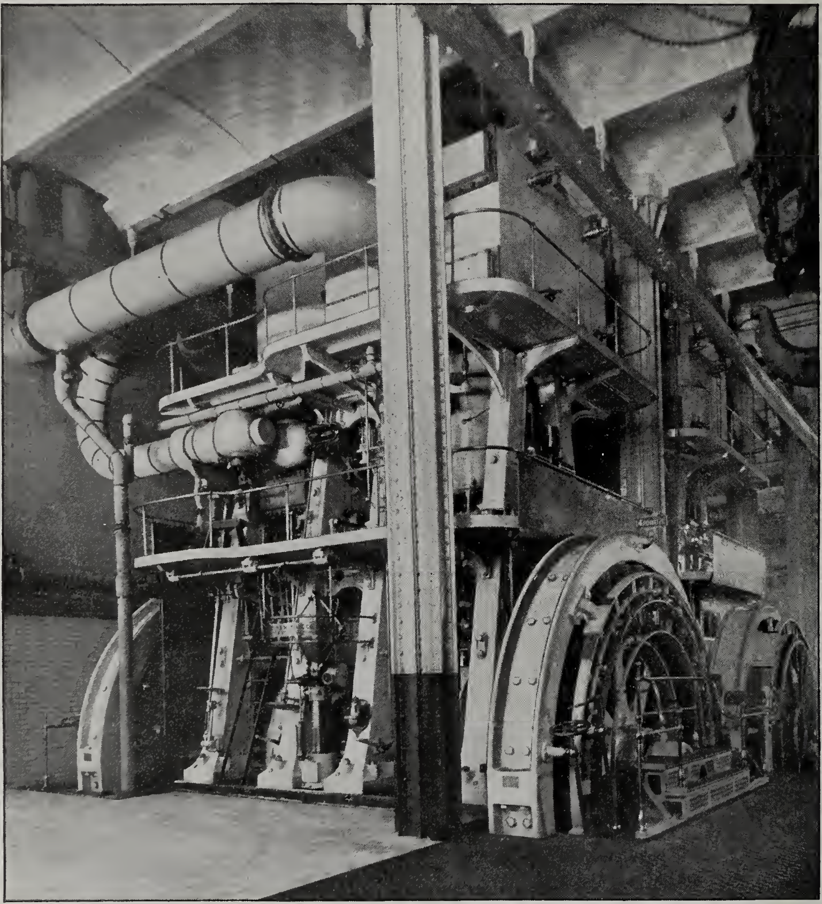
The small amounts of energy consumed in electric heaters are distributed over the time of a working day in much the same way as the motor load, and serve, to a small extent, the same purpose as to uniformity. The service to incandescent lamps extends over the entire twenty-four hours, but is subject to great variations in amount. During the early morning hours, say, from five to eight A. M. in winter, a large number of incandescent lamps are in use. The load drops to a less amount during the middle hours of the day, and again rises so as to reach its greatest maximum at from six to eight o'clock in the evening. From its highest point in the early evening the incandescent load decreases up to about midnight, from which time it remains about stationary until the early morning rise. The load on electric traction stations is similar in time distribution to that on incandescent generators, but the early morning load is relatively larger, though spread over a greater period than the maximum evening load, which latter is very heavy and of only about one hour's duration. Each kind of electric service is limited as to its area of distribution from a single station.



ALTERNATING CURRENT GENERATORS IN A WATER POWER STATION. EQUIPPED BY THE WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURGH & LONDON

Direct current supply for 110-volt incandescent lamps is most prescribed as to its radius of operation, which, for economical results, does not greatly exceed one mile from a single station,

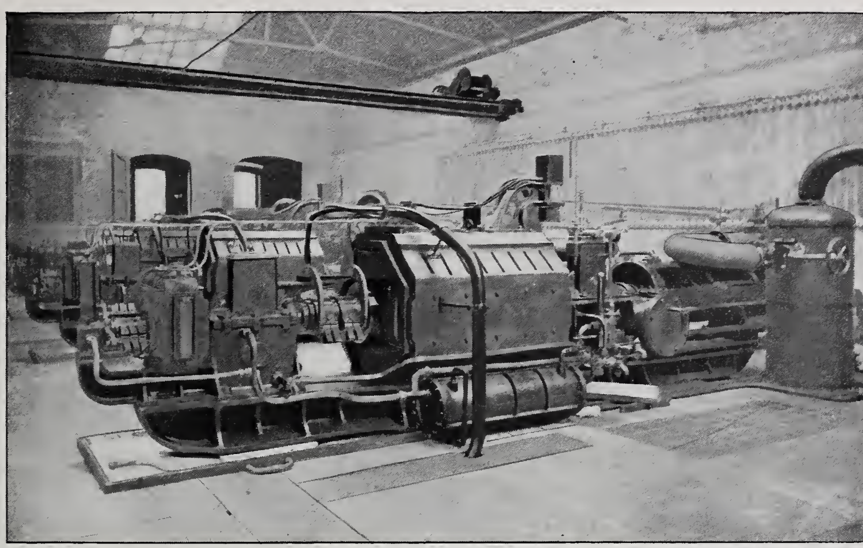
operating on the three-wire system. Direct current distribution over circuits intended only for motors, whether stationary or in use on tramway cars, may be economically carried out over distances of four to five miles, though there are many instances in which power is transmitted to cars at twice these distances.



A 2500 H. P. QUADRUPLE EXPANSION DIRECT-CONNECTED ENGINE IN ONE OF THE STATIONS OF THE EDISON ELECTRIC ILLUMINATING CO., NEW YORK

Power distribution over a ten-mile radius with an electric pressure of from five to six hundred volts, which has become standard for both stationary and car motors, involves in most cases either too great an investment in copper for conductors or too great a loss of power in them.

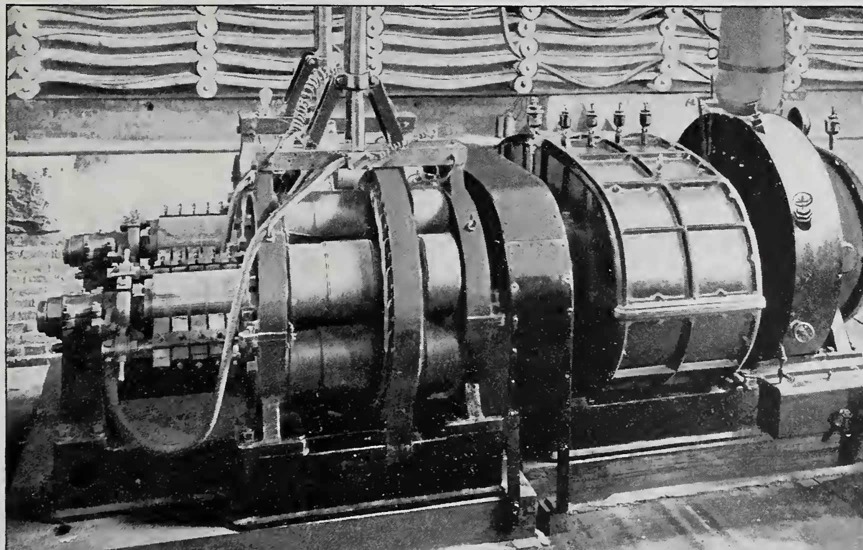
Series arc lamps, the kind used for street lighting, and, to some extent, for interior service, are usually distributed on circuits of from two to six thousand volts pressure at full load, and circuits extending ten or even fifteen miles from a single station can be operated with fair economy. Incandescent lamps may be supplied from alternating current circuits at distances of from two to twenty miles from a single station without serious outlay for copper or excessive loss of power in conductors, according to the so-called primary pressure, or that produced at the station, which, in regular practice, is from one to six thousand volts. The use of alternating current



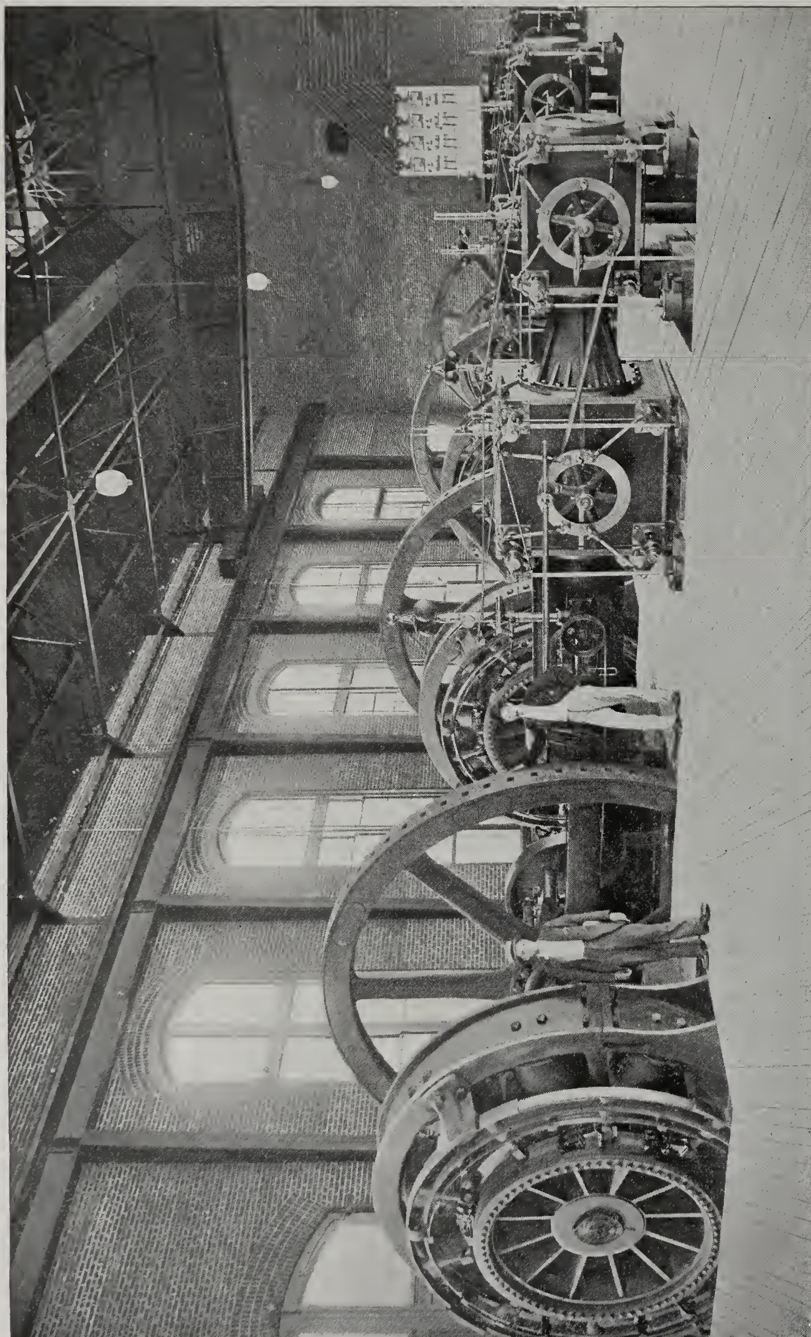
A STATION OF THE METROPOLITAN ELECTRIC SUPPLY CO. EQUIPPED WITH 350 K. W. STEAM TURBINE ALTERNATORS, BY MESSRS. C. A. PARSONS & CO., NEWCASTLE-ON-TYNE, ENGLAND

transformers at the consumer's premises, of course, enables any primary pressure to be reduced to that required for his purposes. As electric heaters are operated from the several regular circuits above mentioned, the distances from a single station at which they may be supplied are the same as those named.

Between the steam engine and the electric lamp every possible economy has already been brought to a high figure. Large electric generators now de-



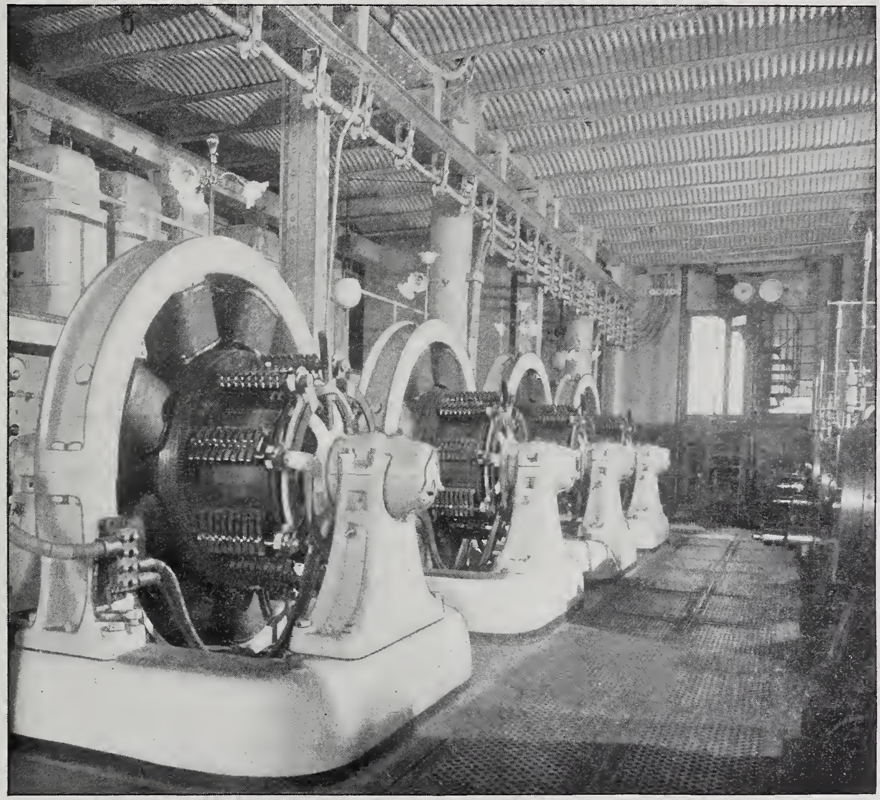
A 300 H. P. DE LAVAL STEAM TURBINE AND DYNAMO. A TEMPORARY INSTALLATION OF THE EDISON ELECTRIC ILLUMINATING CO., NEW YORK



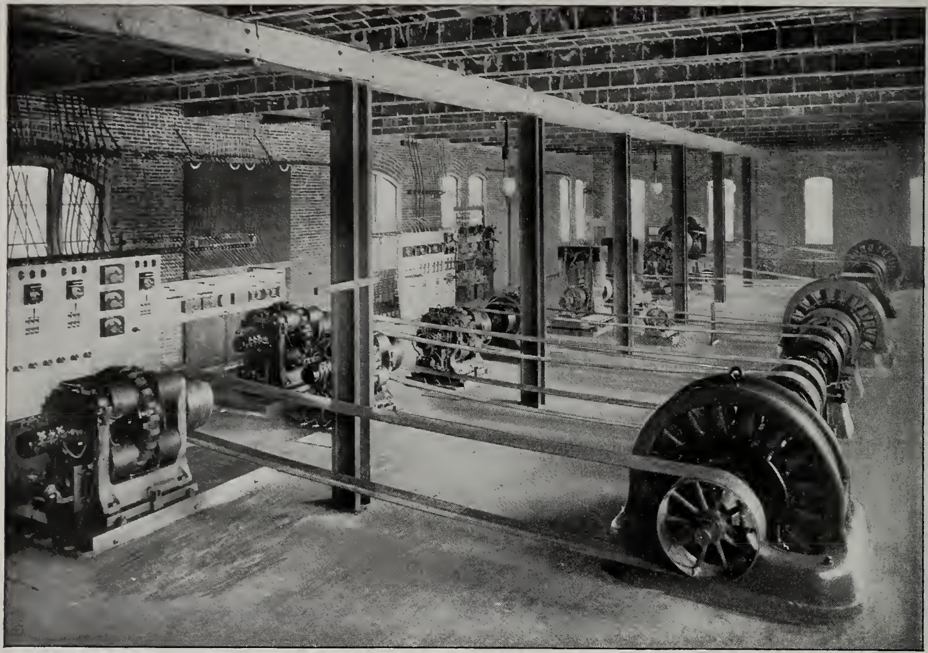
THE BALTIMORE & OHIO BELT LINE RAILWAY STATION AT BALTIMORE. THIS STATION SUPPLIES CURRENT FOR OPERATING THE ELECTRIC LOCOMOTIVES OF THE B. & O. RY. IN THE TUNNEL UNDER THE CITY OF BALTIMORE. FOUR TANDEM COMPOUND ENGINES OF 800 H. P. EACH. BUILT BY THE E. P. ALLIS COMPANY, MILWAUKEE, WIS., U. S. A.

liver more than 90 per cent. of the energy applied to their shafts in the form of electric current at their terminals, and the distribution lines absorb less than 10 per cent. of the energy passing through them on the average. The next increase of economy must be made at the steam engine. The scant 10 per cent. of the fuel energy which are delivered at the fly-wheel or coupling may in many cases be increased with large compound condensing engines and uniform loads to the full capacity of each, when in operation.

The present problem in electric station design is to supply energy over a wide area, in several forms, from a very few large direct-connected engines and dynamos with each generating unit at nearly full load during its time of operation. As the time during which the maximum load is required each day is very short, as the load is constantly fluctuating, and as it is uneconomical to have most of the generating plant stand idle during the greater part of the twenty-four hours, some device is desirable that will either store up or deliver electric energy as required. The main generating station should be located at a point where condensing water can be cheaply had, to which coal transportation is cheap, and from which ashes can be readily removed,—that is, if possible, on a water front. The main dynamos must all furnish the same kind of current, so as to work in multiple, and this current may be either direct or alternating, according to local conditions. If as much as one-half of the total load is near enough to the station to be economically distributed with direct current



A TYPICAL SET OF ROTARY CONVERTERS



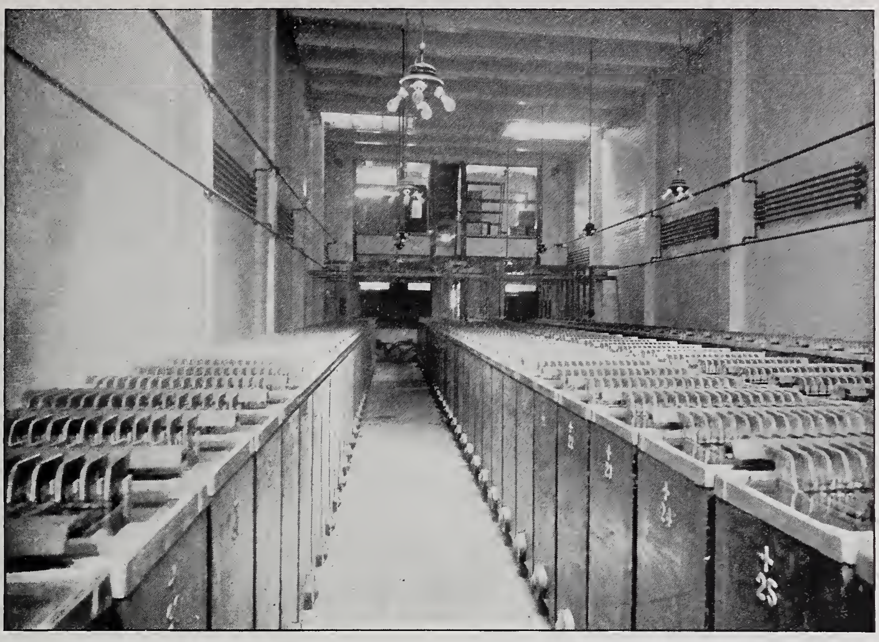
A TYPICAL SUBSTATION. EQUIPPED BY THE GENERAL ELECTRIC CO., NEW YORK. MOTOR AND GENERATOR ROOM

on the three-wire system, then the generating units should produce low-pressure direct current. If much the larger share of the total load is several miles distant, then alternating current of three or six thousand volts should be generated at the main dynamos. This one great, economical, main station, generating current for a wide area, displaces the several small plants that formerly supplied the various forms of electric energy to consumers, but introduces in their places the substation for a like purpose.

Each displaced station had boilers, engines, pumps, steam pipes, firemen, and engineers. The substation requires none of these, but instead has transformers, converters, motors and dynamos, which receive the energy delivered from the generating station and send it out in the forms required by consumers in that vicinity. If direct current series arc lamps are wanted, a transformer and an alternating current motor change energy from the line to mechanical motion on the shaft of an ordinary arc lamp dynamo. If low-pressure, direct current is desired, a transformer and rotary converter supply it, or if higher pressure, direct current is wanted for motor work, it is produced in the same way.

The substation requires but little room, small attendance, and no fuel; it produces no smoke, ashes, or noise, and operates at a very high efficiency. If low pressure, direct current is generated at the main station, a storage battery there will enable a large part of the generating units to be kept in operation for charging purposes during the times of small load, and will reduce the number or capacity of these units necessary by discharging at the times of heavy load. Should alternating current be produced at the main dynamos, the results as to uniform load and discharge of heavy loads are obtained by placing batteries at those substations which distribute low-pressure direct current. Even when direct current is generated by the main dynamos the battery at the generating station is supplemented in its action by others at the substations.

In one large station recently erected



A STORAGE BATTERY PLANT IN A MODERN ELECTRIC LIGHTING STATION. THE EDISON ELECTRIC ILLUMINATING COMPANY, NEW YORK

to displace several smaller ones, four direct-connected generating units of 2000 horse-power each, supply alternating current at a pressure of 2000 volts, and this current is transmitted direct to consumers' premises. The high-pressure direct currents for arc lamps in this case are produced in the same station, a few feet from the main generators, with motor-driven arc dynamos. Five-hundred-volt motor circuits are also fed at the above plant from rotary converters. In this case the main substations may be said to be combined in one, which is practical from the fact that the direct current loads are not very distant from the plant and are supplied at rather high pressure.

In another recent plant the main station generates many thousand horse-power of three-phase alternating current at about 6600 volts pressure, and distributes its energy through ten substations over an area of more than one hundred square miles in every standard form of direct and alternating current service. Most of the substations in this case are supplied with storage batteries, and the load-factor is said to be 80 per cent.

The development of electric stations thus indicates and includes the following practice:—

Great loads and large areas are supplied from a single generating station. The main dynamos produce electric energy in but one form, and all work together on the same load when desired. For service distant from the main station high-pressure currents are transmitted to substations and there transformed to the character required by consumers.

Storage batteries are used at the main, or substations, or both, to absorb electric energy at times of light load and deliver it at times of heavy load. The storage battery decreases the necessary amount of generating equipment, and insures a constant working pressure.

Finally, belts and shafting are done away with, and a variety of machines, scattered over a wide area, are held in step at their proper speeds by the powerful, unseen grasp of the electric current.

MECHANICAL ENGINEERING IN MODERN SHIP-BUILDING

By Sir William H. White, K. C. B., LL.D., D. Sc., F. R. S.

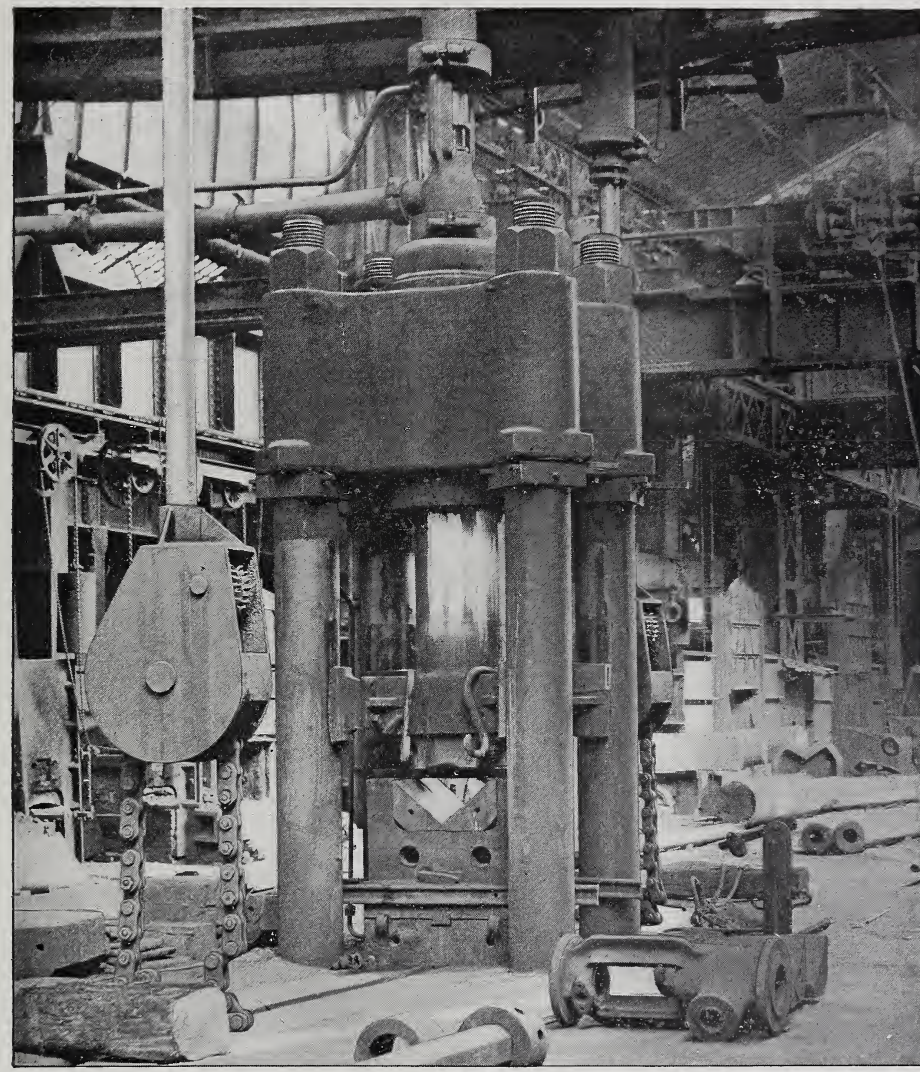
AS in some measure related to Sir William H. White's admirable paper on "The Progress in Steam Navigation" which appeared in the November number of this magazine, it was thought desirable to print here as well the recent review by the same author, before the Institution of Mechanical Engineers, of the directions in which shipbuilding and the working of ships have been influenced by mechanical engineering. The subject was treated under the two principal heads of "Mechanical Engineering in the Shipyard" and "Mechanical Engineering on Board Ship," and as of possibly additional interest there have been incorporated with the text here a number of photographic reproductions of shipyard tools and equipments, marine engines, and auxiliaries, specially prepared for this purpose.—THE EDITOR.

MECHANICAL ENGINEERING IN THE SHIPYARD

So long as wood was the principal material employed in shipbuilding, manual power reigned supreme in the largest and best equipped shipyards, including the Royal Dockyards. Machinery was used little, if at all, in the operations of shaping, fixing, combining and fastening the various parts of ships' structures. Remarkable results were achieved under these conditions. The towering three-deckers, now serving as hulks at our great naval ports, are monuments of the constructive skill of the shipwright, based on the experience of centuries, with wood as his material and only simple hand-tools. If I may refer to my own recollections, when, as a lad, I entered Devonport Dockyard forty years ago, it may serve to illustrate the changes that have occurred since that date in shipyard equipment. A Royal dockyard then had its steam factory and machine shops for the repair of engines and boilers; a millwrights' shop for dealing with ship fittings; its steam saw-mills for converting timber; its roperies with suitable machines; and special departments for block-making or other manufactures. A few steam-hammers were to be seen in the forges. Steam cranes and capstans were installed around the basins, and steam pumps were used for the docks. But for shipbuilding proper, manual labour held its own. Individual pieces of the structure were shaped by hand and lifted by hand-power winches, as their size and weight were not considerable. Attempts were made from time to time to introduce new machines and to diminish hand-labour. Few of these succeeded. Even in the joiners' shops wood-working machines were then but little used. One incident dwells in my memory. An experimental machine was erected for cutting out the frame timbers (for "ribs") from the logs. It was ingeniously contrived to cut curved and bevelled timbers for large warships, and to relieve the sawyers from the heaviest work. After an extended trial, however, in competition with the hand-sawyers, it was agreed that they could beat the machine, and its use was discontinued.

The contrast between these conditions and those now to be seen in a modern shipyard is extreme. Machinery and

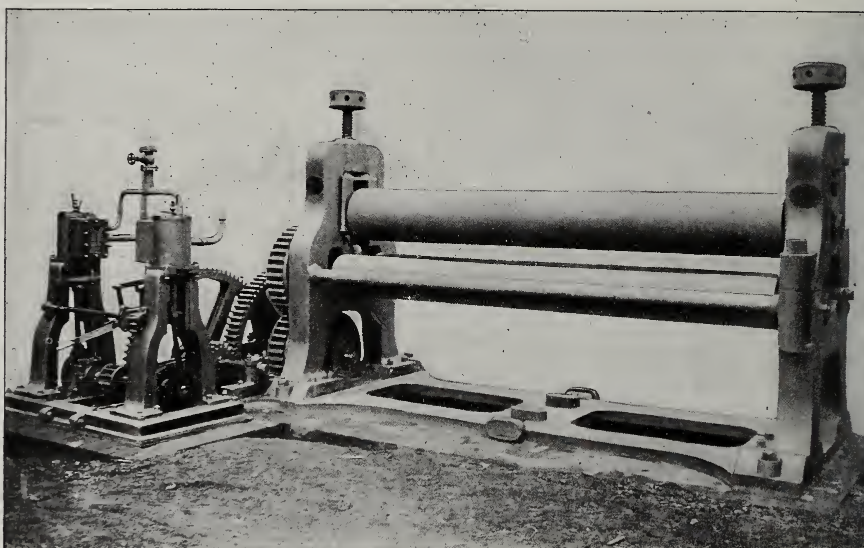
labour-saving appliances abound, and are essential to rapid and economical working. With ships of increased dimensions scantlings have become heavier, the sizes and weights of plates and eration is given to every step necessary in dealing with materials, from their delivery up to the time when they find their places in the structures of ships. The stacks of plates and bars are so sit-



A FORGING PRESS AT THE ELSWICK WORKS OF SIR WM. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE, ENGLAND

bars have increased, special arrangements have to be made for transporting and handling materials, and the power of all classes of machinery has had to be increased proportionately. In a well-equipped yard the most careful consid- uated that the materials can be readily lifted from the trucks on arrival, or out of the dépôt when required for use. Travelling cranes, or gantries, command the whole dépôt. Bogies, in many cases running on light railways, convey the

materials to the machine shops, furnaces or bending slabs, where they are shaped and prepared for erection, afterwards being similarly transported to the building slips. A large number of cranes are used for handling the materials with a minimum of labour while at the machines. At the building slips also mechanical lifting appliances are freely used. Hitherto, manual power has been chiefly employed in fixing and riveting together the several parts of the structure. Serious attempts are now unusual thickness. Messrs. Swan & Hunter, of Wallsend, near Newcastle-on-Tyne, have adopted another plan. Shipbuilding sheds of special design have been built over the slips. These sheds give shelter to the workmen in bad weather, and facilitate many of the operations of erecting and fastening parts of the structures. They also carry a very complete arrangement of overhead electric cranes, which travel the whole length of the slips. These cranes lift and put in place frames, beams, and



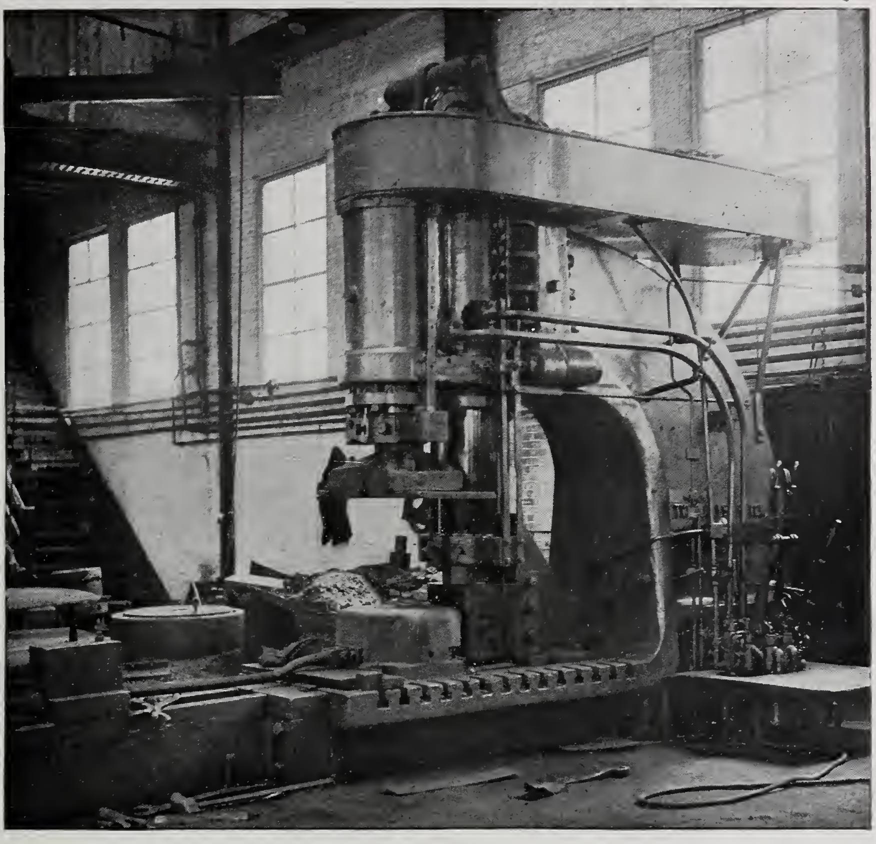
A PLATE BENDING MACHINE. BUILT BY MESSRS. THORNTON & CREBBIN, BRADFORD, ENGLAND

being made to extend the use of machinery even to those portions of the work.

Some of the leading firms have erected at their building slips large travelling cranes or gantries, capable of moving along the lengths of the slips, as well as commanding the whole breadth. These locomotive lifting appliances can be used for both erecting and putting into position parts of the structure, as well as for carrying portable machine tools. Messrs. Harland & Wolff made use of a very large installation of this kind in building the *Oceanic*. Hydraulic power was chiefly employed by them, and powerful machine-riveters were also used extensively, the plating being of

plates, as well as carry certain machine tools. At the Newport News shipyard, in the United States, electrical appliances have been adopted for work of a similar nature. In all these cases it is understood that the large initial outlay has been justified by experience, especially in building heavy ships. This is readily understood, when it is remembered that from 7000 to 10,000 tons of material have to be built into the largest ships of the present day, and traversed over lengths of 500 feet to 700 feet, as well as lifted to great heights in many cases.

Some firms are content with simpler arrangements, such as derricks with

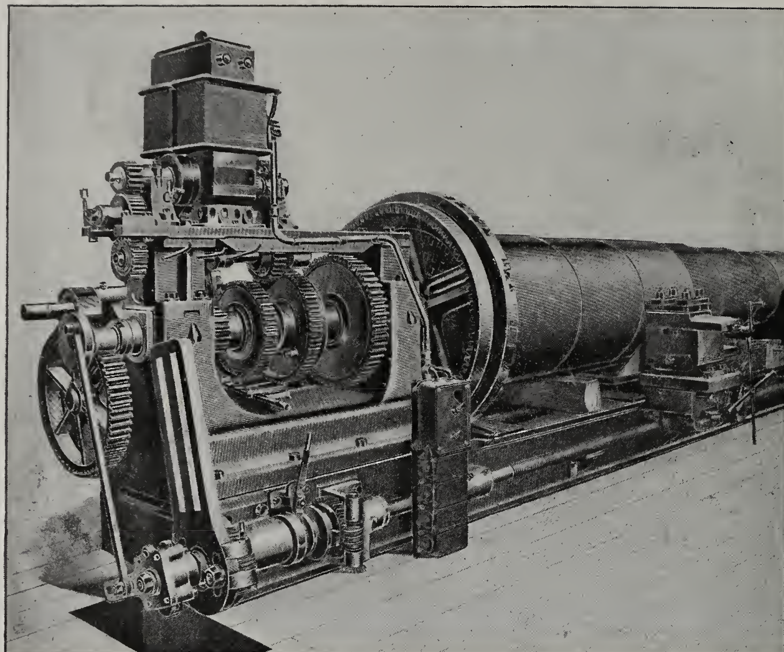


A HYDRAULIC FLANGING PRESS FOR HOT WORK AT THE UNION IRON WORKS, SAN FRANCISCO, U. S. A.

mechanical power for lifting. No doubt such devices are of real service, and they permit of easier readjustment under the varying conditions of shipyard work. Ships have grown rapidly in size, and will probably continue to do so. With more elaborate and permanent appliances there is a difficulty in foreseeing what margin should be provided beyond the maximum requirements of the period when the appliances are designed. In the Royal Dockyards, for example, and in some private yards where sheds existed over building berths, they have had to be removed in order to provide for ships of unprecedented dimensions. I have seen cases where ordinary sheerlegs, with mechanical power for hoisting, have been found more useful for fitting armour-plates on the sides of a battleship than travelling steam cranes. Facts of this nature, however, in no way contradict the general principle that well-considered lifting appliances are of great utility in building ships.

In the early days of iron shipbuilding the machine tools of shipyards were comparatively few and simple, mostly borrowed from boiler-shop practice. Since then shipyard machinery has been greatly specialised, and re-construction of plant has become necessary from time to time, in order to meet changed conditions. At first steam power alone was used. Now hydraulic, electrical, and pneumatic power are used as allies to, or substitutes for, steam power.

Hydraulic power, as a rule, finds its most general use in cranes and other lifting appliances, as well as in powerful presses used for flanging, "joggling,"



AN ELECTRICALLY DRIVEN LATHE FOR PROPELLER SHAFTS. BUILT BY MESSRS. BEYER, PEACOCK & CO., MANCHESTER, ENGLAND. OWING TO THE GREAT LENGTH OF THE LATHE, ONLY A PORTION, SHOWING ONE REST, IS GIVEN

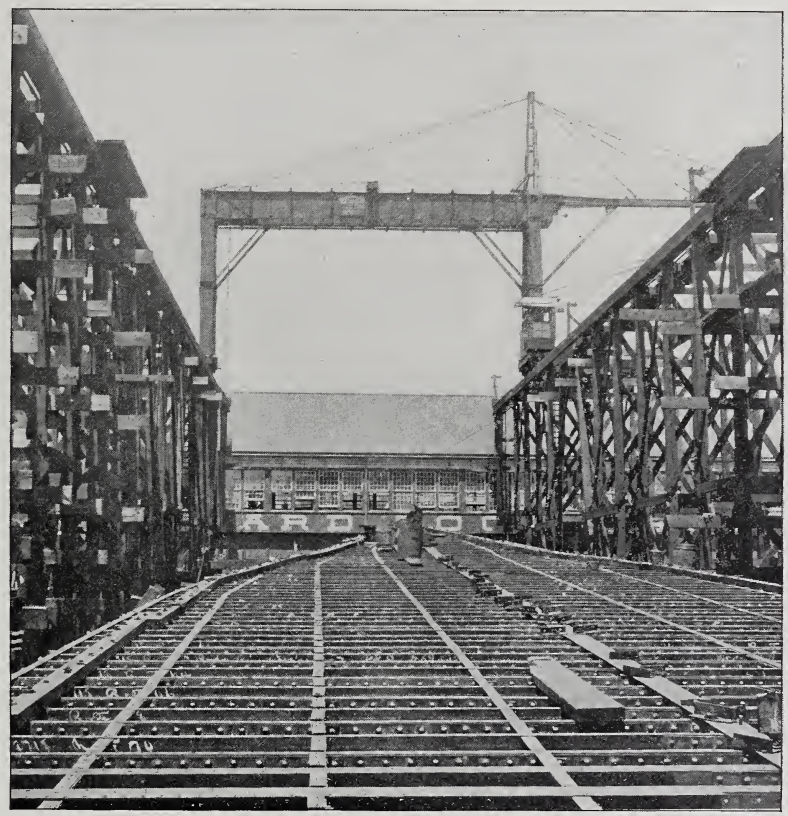
punching out lightening holes, and other heavy work. It is also used for riveting work that can be brought to the machines, and to a limited extent for portable riveters.

Electrical power is being extensively used in some of the best-equipped shipyards, apparently with satisfactory results. It is probable that the system will be much more extensively employed before long. For large machines with separate motors, and for groups of smaller machines, electric driving has much to recommend it. For operations that have to be performed *in situ*, portable electric machines are found most useful. As examples, reference may be made to electric drills, planers for wood decks, cutters for large holes in plating on sides or decks, caulkers, and riveters. In some cases, especially in elaborately fitted warships, it is found advantageous to establish on board temporary machine shops, which can be most conveniently driven by electric power. Many operations are thus rapidly and economically performed which would otherwise necessitate the transport of fittings to and from shops in the yards. Portable electric light plants for use on board ships while building are now generally recognised to be advantageous and economical. The arrangements made for lighting are readily extended to include driving the machines above mentioned.

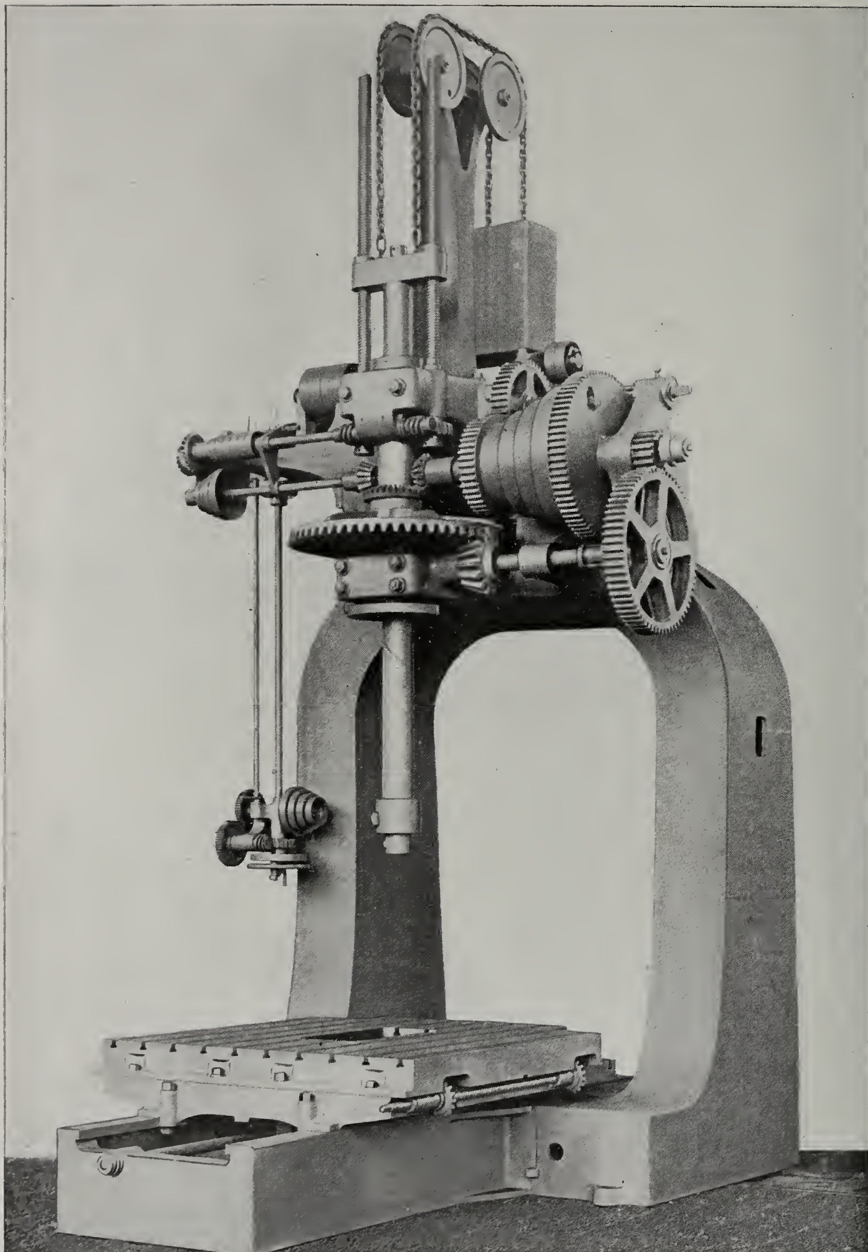
Pneumatic power has not been much used in shipbuilding. It has found employment, however, for such operations as caulking and riveting. Mr. Babcock, of Chicago, has recently published the results of his experience with pneumatic riveters, and he is strongly of opinion that they can be advantageously adopted for work at the ships. As a rule, nearly all such work is done by hand, although machine-riveting is largely used for work that can be taken to machines. Every shipbuilder would be g'ad to have a light and satisfactory portable riveting machine, which could be used in all the varying positions and conditions occur-

ring in shipwork. Many attempts have been made to find a mechanical substitute for the heavy manual labour involved in satisfactorily " closing " and riveting shell and deck-plating. If this can be done there should be a considerable economy in costs, and many disputes with workmen would be avoided. As yet success has not been attained except with special appliances, such as have been described as erected by Messrs. Harland & Wolff, for carrying hydraulic riveters, or others used for riveting garboard strakes and keels. I have seen steam riveters and electric riveters under trial, and now good things are said of pneumatic riveters. Here is an opening for the mechanical engineer, who should master the essential conditions by careful observation of shipbuilding practice as a preliminary to his design of a suitable riveter.

In all branches of engineering it is essential to economy of production that the manufacturer should furnish materials of the dimensions and forms best adapted to combination in the structures to be produced. In floating structures such as ships, economy in weight, with adequate provision of strength, is of the highest importance, resulting in corresponding addition to carrying power and earnings. Even if economy of weight has to be obtained by increased first cost of materials, it is, as a rule, well worth having; and in many instances carries with it savings in the cost of construction. The principle is sound enough and has long been recognised, especially in warship building.



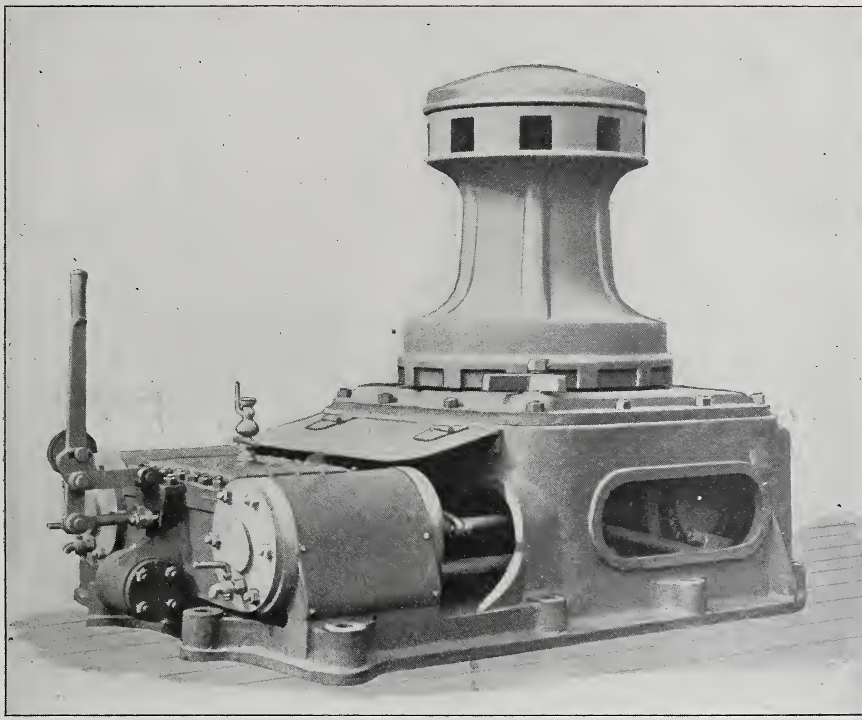
A GANTRY CRANE IN THE SHIPYARD OF THE HARLAN & HOLLINGSWORTH CO., WILMINGTON, DEL. U. S. A.



A HEAVY VERTICAL BORING MACHINE WITH EIGHT-INCH SPINDLE. BUILT BY MESSRS. THOMAS SHANKS & CO., JOHNSTONE, SCOTLAND

With iron as the material, it had not nearly the same range of application as is now possible with steel. Special sections of bars and beams are readily produced in steel which were hardly obtainable in iron. Z-bars, H-bars, channel bars, T-bulbs, angle bulbs, and other sections, have come into general use, taking the place of built-up combinations of plates and angles with rivet connections. Economy in weight and labour is thus obtained, but special appliances are needed for working some of these special sections. With steel much larger plates are produced and riveting is lessened. In the *Oceanic* the majority of the plates in the central portion of the vessel are said to be over 28 feet long, about 4½ feet wide, and from two to three tons each in weight. Iron plates 12 feet to 14 feet in length and 3 feet to 4 feet in width would have been considered of large dimensions, and the riveting work in butts and edges would have been proportionately greater than with the larger steel plates.

The shipbuilder is under great obligations to the steel-maker for this progress in manufacture; but the mechanical engineer has had a hand in its achievement, by designing and making the plant used in the steel-works. In the device of new and more powerful machines for the shipyard his work has been more obvious. Without such machines the superior working qualities of steel could not have been utilised as is now done. Operations are now commonly performed on steel plates in a cold state that were not possible with the best qualities of iron. Flanging is extensively practised, to form stiffeners or to make connections such as were usually formed in iron ships by riveting on angles to plates. The edges of skin-plating and deck-plating are "joggled," and the use of "liners" or "packing pieces" is avoided. Steel plates are bent



A STEAM WARPING CAPSTAN. BUILT BY MESSRS. CLARKE, CHAPMAN & CO., LTD., GATESHEAD, ENGLAND

COPYRIGHTED BY MESSRS. W. GREGORY & CO., LONDON

A 50-TON CRANE AT PORTSMOUTH DOCKYARD, ENGLAND

and worked to difficult forms necessary in certain parts of ships where castings were formerly used. Lightening holes are punched out of comparatively thick plates, and in many other ways weight and cost are reduced by the use of special machines. Many of these are worked by hydraulic power, and it is difficult to imagine a better application of that power than is seen in modern flanging and punching machines.

In concluding these remarks on shipyard machinery it may be of interest to briefly enumerate some of the principal machines now in use.

Flanging Machines. — Capable of flanging cold at one stroke plates up to 33 feet in length and 1 ¼ inches in thickness. Less powerful machines are used for thinner plates up to ¾-inch. Most of these machines are hydraulic.

Joggling Machines.—Capable of deal-

ing with plates up to 1 inch in thickness; also with angle-bars. Most of these machines are hydraulic.

Shearing Machines. — Capable of shearing plates up to 2 inches in thickness; and of dealing with Z-bars and angle-bars. These very thick plates occur in the protective decks of warships.

Punching and Lightening Machines. —Capable of punching large lightening holes out of plates 1 inch thick at one stroke. Also of punching rivet-holes in plates up to 1½ inches thickness. A few can punch up to 2 inches thickness.

Bending Rolls.—Capable of bending plates 30 feet to 35 feet long and 1½ inches thick.

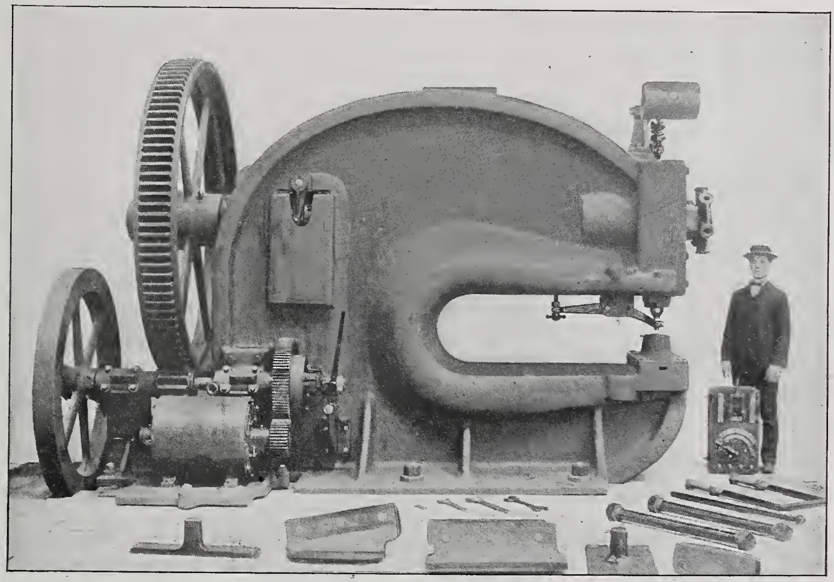
Straightening Rolls. — Capable of dealing with plates 7 feet wide and 1½ inches thick.

Planing Machines.—Capable of dealing with plates up to 35 feet long, or batches of plates. Some of these machines plane, edge, and butt simultaneously.

Bevelling Machines. — Capable of dealing (hot) with angle-bars and Z-bars.

Radial Drills and Countersinking Machines.—Fitted with revolving arms, 8 feet long, traversing through 180 degrees; capable of drilling holes up to 3 inches in diameter, or much larger holes with special cutters. Countersinking machines can deal with 700 to 1200 holes per hour, according to thickness of plates.

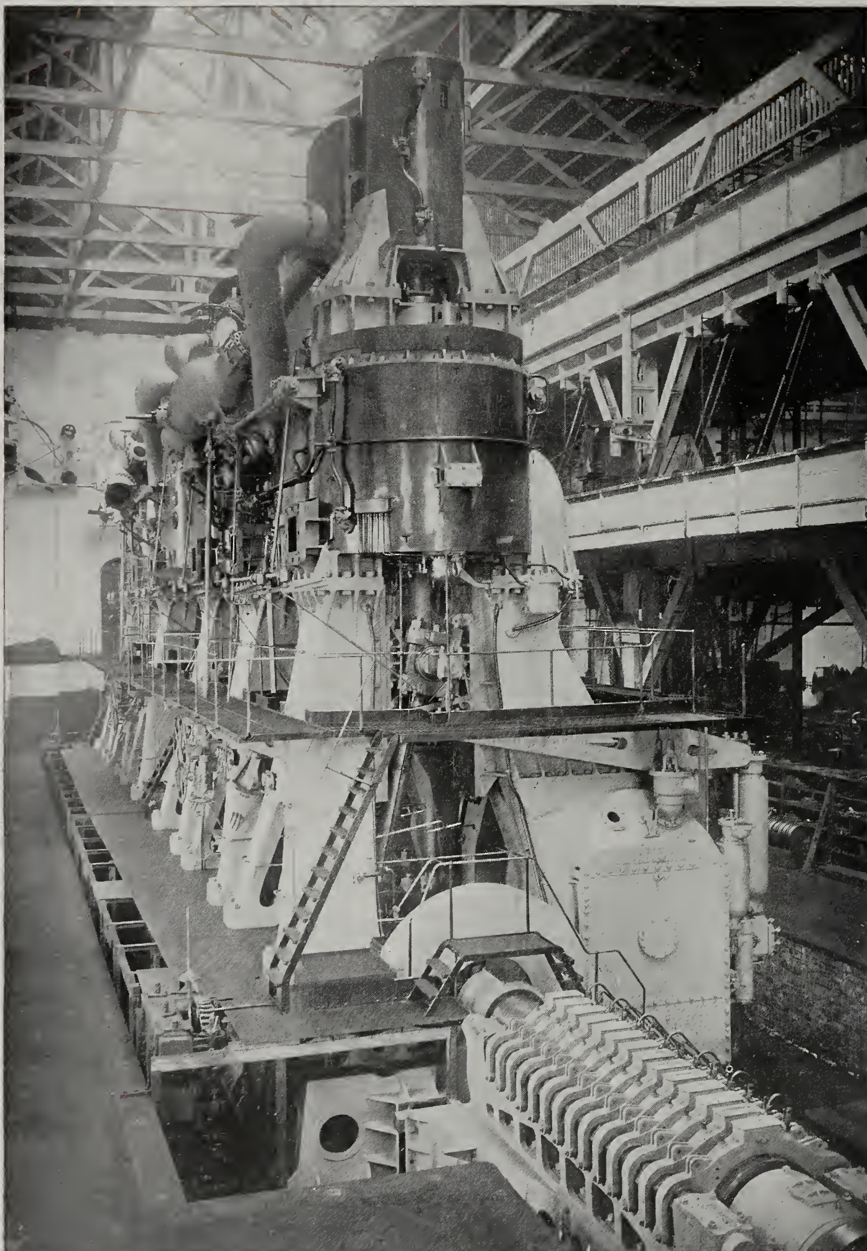
Most of the larger shipyard machines are now fitted with hydraulic lifts and cranes, for dealing with plates, etc., while they are at the machine, and lifting them on and off the bogies or trucks on which they are transported through the yard.



A HEAVY PUNCH FOR SHIPYARD RIVET PUNCHING, MANHOLES, HANDHOLES, &C.
BUILT BY THE HILLES & JONES CO., WILMINGTON, DEL., U. S. A.

MECHANICAL ENGINEERING ON BOARD SHIP

The development of mechanical appliances for the equipment and working of ships during the last forty years is no less remarkable than that in connection with shipbuilding. At the earlier date, apart from the propelling machinery, manual power only was employed in the



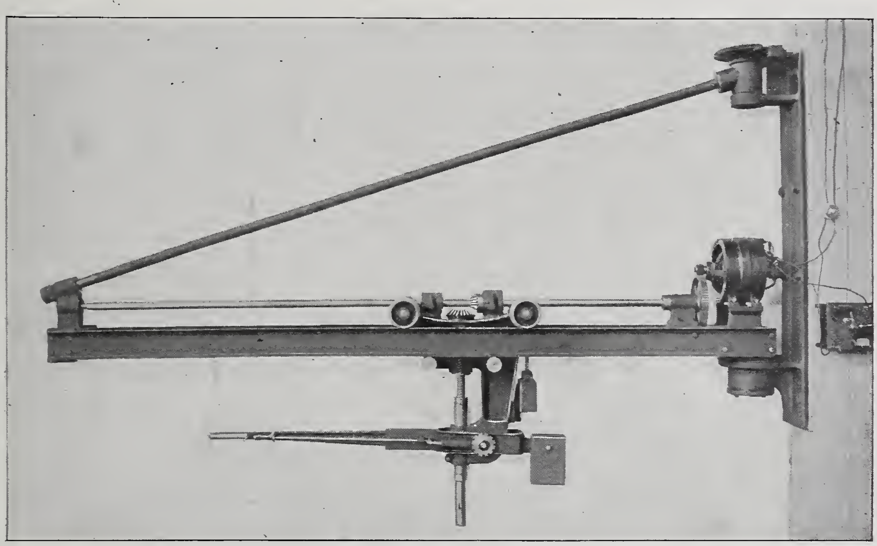
THE TWIN SCREW ENGINES OF THE CUNARD LINE STEAMER "CAMPANIA," I. H. P. 30,000. FOUR CYLINDERS, 37 INCHES IN DIAMETER; TWO CYLINDERS, 79 INCHES; FOUR CYLINDERS, 98 INCHES. BUILT BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LTD., GOVAN, GLASGOW

largest and best-found ships. Work on masts and sails, steering, loading and unloading cargo, lifting and lowering boats was all done by hand-power, aided by simple mechanical appliances. In warships the armaments were hand-worked; gun carriages, training gear and ammunition-supply were all of the simplest character, and practically unchanged in principle as compared with those which had been used for centuries.

The first sea going British ironclad, the *Warrior*, laid down in 1859, may be taken as an example of the best practice at that time. In the original design steam power was applied, apart from propulsion, only to pumping and ash-hoisting. The pumping was partly done off the marine engines and partly by an auxiliary engine (added during the building), which also worked the ash-hoisting gear by means of chain and spur gearing. A full equipment for sailing was provided; all the work in this department was done by hand. When the vessel sailed, the screw propeller was raised out of the water in its banjo-frame. A weight of 32 tons had to be lifted, and this was done by means of special purchases. In working spars and boats, the heaviest weights dealt with were from five to six tons. Steering was a formidable operation. Between the steering wheels and the tillers there was a multiplication of tackles to gain power, and at full speed forty or fifty men worked at the wheels and relieving tackles, even then moving the rudder very slowly, and to moderate angles. Heaving in anchors and cables was a slow and laborious operation, accomplished by fitting capstans on two decks and crowding men on the bars.

In the mercantile marine the conditions were very similar. Cargo steamers were equipped with hand-worked appliances for loading and unloading. The winches were similar in character to those used from early times in sailing ships, the lifting power being moderate, and working slowly except with light loads. Handpower was used for cable work, steering, and working spars and sails.

Now the conditions of working are entirely changed. Mechanical power is extensively employed, manual power is minimised, comfort and habitability are enormously increased, steering is made easy in the largest and swiftest vessels,



AN ELECTRICALLY DRIVEN COUNTERSINKING MACHINE. BUILT BY MESSRS. PRENTICE BROTHERS, WORCESTER, MASS., U. S. A. USED FOR COUNTERSINKING LARGE HOLES IN SHIP PLATES

A 125-TON FLOATING DERRICK, AT THE WORKS OF WILLIAM CRAMP & SONS SHIP & ENGINE BUILDING CO., PHILADELPHIA

loading and unloading cargoes are accelerated, and anchors and cables are worked safely and rapidly by a few men.

Without entering into details, it may be interesting to glance at a few of the principal applications of mechanical power, and their influence on the working of ships.

Steering.—Steering naturally takes the first place. In the introduction of efficient steam-steering appliances Mr. Macfarlane Gray has played a distinguished part. I learn from him that the first steps were in 1866, as the result of difficulties that had occurred in steering the *Great Eastern*, and on the suggestion of the late Sir James Anderson, who was the commander of that ship. Mr. Gray's invention of the differential gear enabled the steering engine, when placed at a distance from the navigating station, to be controlled by the movement of the steering wheel, so that the helm could be made to follow and assume any desired position. The first trial on the *Great Eastern* was made in March, 1867, and proved successful. It led eventually to the general adoption of steam-steering gear, although some time elapsed before the full advantages were realised.

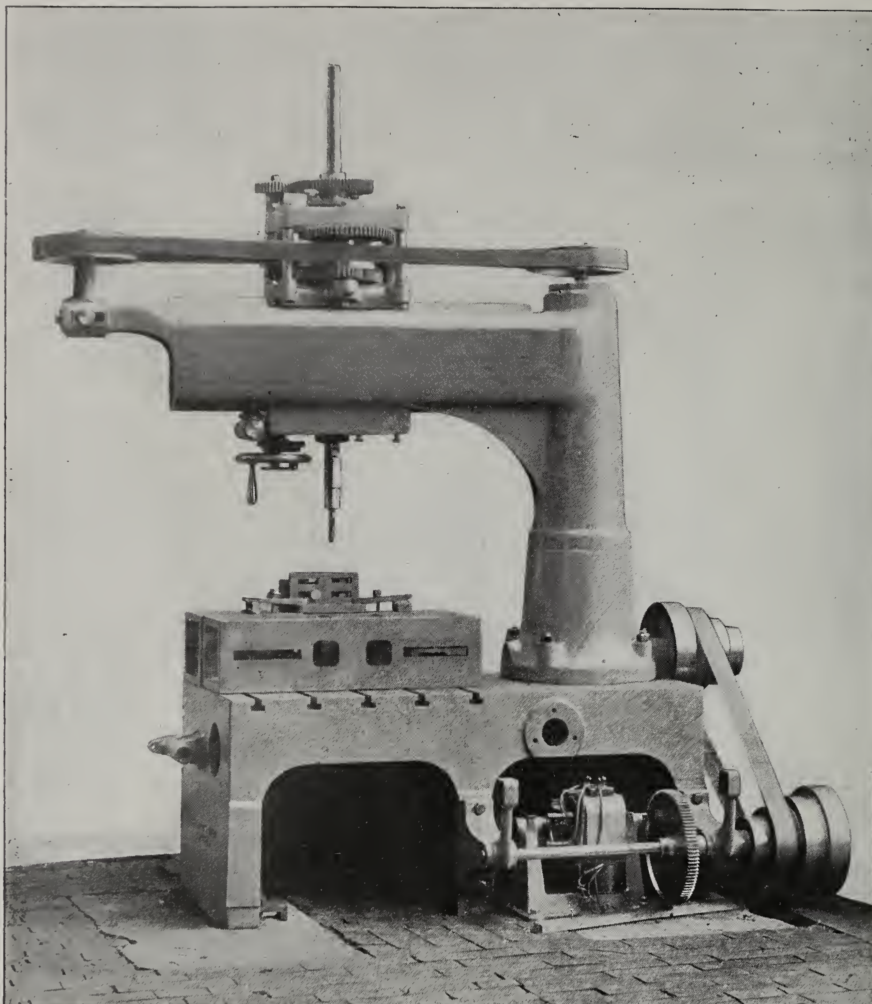
The British Admiralty took the system up on the recommendation of Sir Nathaniel Barnaby, and applied it to the *Minotaur* class,—the longest warships then afloat,—where difficulties in steering by hand had occurred. No better illustration could be given of the advantages of steam-steering than are afforded by the trials of the *Minotaur*. With manual power eighteen men were employed at the wheels and sixty at relieving tackles. They took 1½ minutes to put the helm over to 25 deg., and 7⅔ minutes were occupied by the ship in turning through 360 deg. After steam-steering was adopted, two men at the wheel put the helm over 35 deg. in 16 seconds, the ship turned in 5½ minutes and in two-thirds the space. For all ships such a gain in manœuvring power is of immense value; for warships the utmost handiness is essential, and their rudders are proportionately much larger and more difficult to work. No wonder, therefore, that nearly all steamships are now fitted with mechanical steering gear, mostly steam, in some instances hydraulic, and in a few recent ships electrical. Many arrangements have been devised subsequently for effecting the same object as was attained by Mr. Gray. Some of these are remarkably ingenious. It is but right, however, that he should have the credit of being the pioneer in this important change.

As an example of the latest practice in the Royal Navy, it may be stated that in a first-class battleship or cruiser there are two independent steering engines, each of wihch can move the rudder through 70 deg. in 30 seconds when steaming at 18 to 23 knots. The maximum turning moment on the rudder head, in the case of a battleship steaming at 18 knots, is estimated at 450 foot-tons.

Proposals have been made, and some of them have been worked out in detail, for automatically steering ships on a given course. While this is a mechanical possibility, the system has not found favour in practice, nor is it likely to do so. Under the actual conditions of navigation there is obviously a constant need for human watchfulness and control, while the maximum economy obtainable by the use of such automatic steering gear is comparatively unimportant.

Capstans, Windlasses, and Cable Gear.—Manual power has practically ceased to be used for working anchors and cables in steamships. Steam power is generally employed, hydraulic power has been used in some cases, and electrical power is coming into use. Anchors and cables in the largest ships are too heavy to be satisfactorily dealt with apart from mechanical appliances, and in smaller vessels similar appliances economise labour.

These appliances have to be devised in such a manner as will fit them to withstand sudden and severe shocks and stresses inevitably occurring in service, while they must be capable of controlling the cables when at anchor or when mooring or unmooring. The details of



AN ELECTRICALLY DRIVEN RADIAL DRILL. BUILT BY MESSRS. GREENWOOD & BATLEY, LTD., LEEDS, ENGLAND

the mechanism in modern capstans and windlasses show great ingenuity, as well as capacity for standing rough usage.

In the Royal Navy it is the practice to fit capstans so that they can be worked either by hand or by power. Taking a large battleship of 15,000 tons, the forward capstans have to deal with $2\frac{9}{16}$-inch cables, weighing 16 tons for each 100 fathoms, and with anchors each weighing 6 tons. It is required that these capstans shall be capable of lifting 35 tons at a speed of 25 feet per minute, and this is practically tested in each ship.

In the largest classes of merchant steamers cables up to $3\frac{1}{4}$ inches are now used, whereas thirty years ago there were few vessels with more than $1\frac{3}{4}$-inch cables. The speed of lifting the anchors does not usually average more than 40 feet per minute.

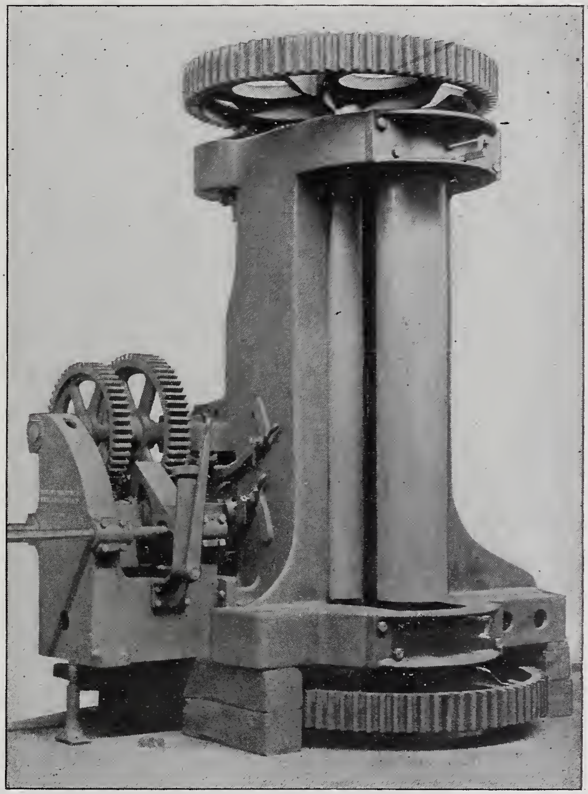
Ventilation. — Artificial ventilation, chiefly by means of fans, is now very largely employed in many classes of ships, and especially in warships. The

arrangements include both supply of air to the stokeholds and furnaces, and supply to the living spaces. In some instances the living spaces are dealt with by exhaust fans, a natural supply of fresh air being depended upon. Perhaps the greatest demands arise in connection with the general adoption of systems of mechanical draught to stokeholds and furnaces supplementing the funnel draught. All these requirements affect the work of the mechanical engineer, leading to the construction of new types of fans and fan engines.

Electrically-driven fans are now coming into extensive use on shipboard, and are an excellent application of that form of power. Cases have often occurred in warships where the introduction of a steam-driven fan for the purpose of ventilating a compartment situated low down in the hold and containing machinery, has been of doubtful benefit. The effect of a better air supply has been almost neutralised by the additional heat caused by the fan engine and its steam connections. With electricity difficulties of this kind can be avoided and other simplifications made, including smaller air shafts, better maintenance of water-tight subdivision, and less waste of power.

Warships, with their complete subdivision, armament and protection, present the most difficult problems. In them it is necessary to provide for ordinary conditions of navigation or service in very varying climates, as well as for the special case where they are in fighting trim, with all the hold spaces below the protective deck closed down, and most of the doors in water-tight bulkheads also closed.

As an example of recent practice, not the latest, it may be stated that in a first-class battleship, outside the machinery and boiler spaces, there are fifteen 24-inch fans driven by electric motors, each fan being capable of delivering 1500 cubic feet of air per minute at the end of its air trunk. In the boiler rooms there are ten fans, 6½ feet in diameter, driven by open double-acting



VERTICAL BENDING ROLLS FOR SHIP PLATES. BUILT BY MESSRS. BEMENT, MILES & CO., PHILADELPHIA

steam engines; and in the engine rooms, two similar fans.

Passenger steamers of high speed are commonly fitted with powerful ventilating appliances, both for living spaces and for machinery and boiler spaces. In these vessels the conditions are simpler than in warships. Cargo steamers also require careful treatment as regards ventilation, especially with certain kinds of cargo, such as coals and oil.

THE HAMBURG-AMERICAN LINE STEAMER "PRETORIA" IN THE FLOATING DRY-DOCK OF MESSRS. BLOHM & VOSS, HAMBURG. THE "PRETORIA" HAS FOURTEEN STEAM WINCHES AND EIGHT STEAM CRANES

Internal Lighting.—In all classes of steamships electric lighting is becoming the rule, and no better evidence of its advantages need be required. While it is most desirable in living spaces, it is practically essential to good working and efficient maintenance of machinery. For ship purposes special water-tight fittings are desirable. In other respects the installations present no special features requiring mention. In warships the "searchlight" fittings are of a powerful character. In merchant ships less powerful lights suffice.

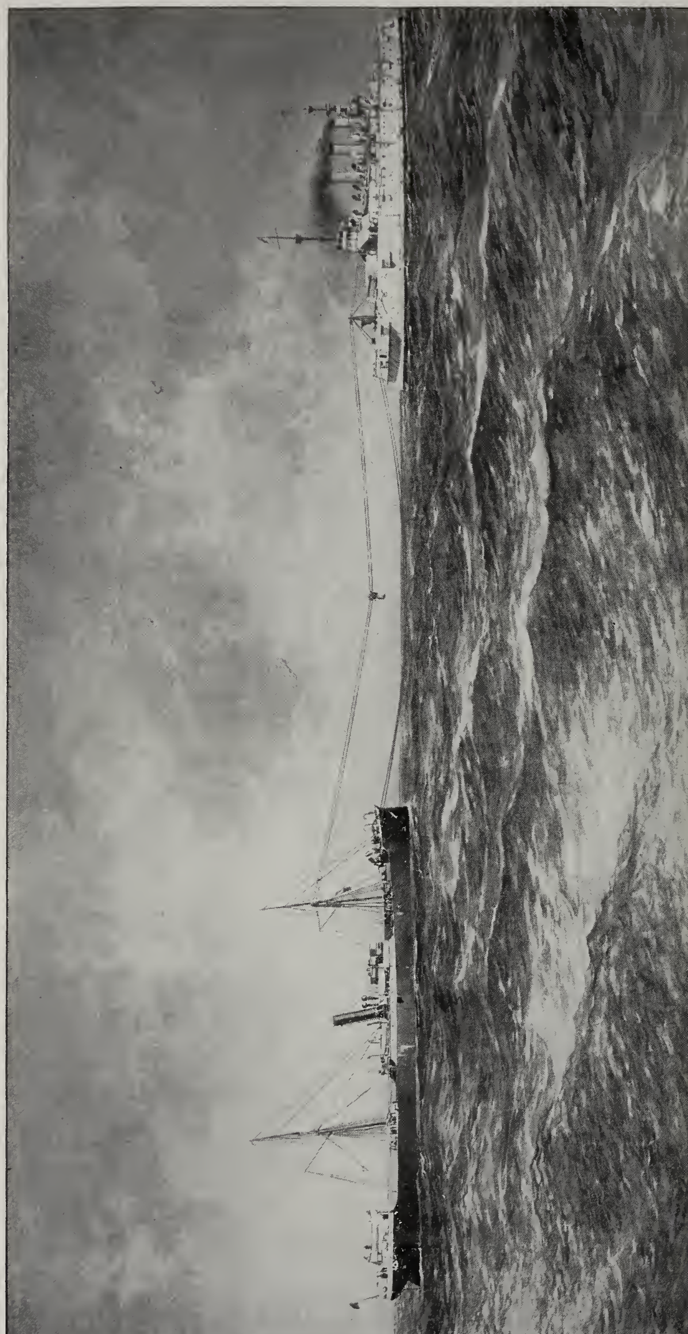
It is probable that the general adoption of internal electric lighting will tend to a wider use of electrical power for many auxiliary purposes. A notable effect on the working of all classes of ships has been produced by the introduction of electric lights. The passage of the Suez Canal is now made by night as well as by day; ports are entered and left at night with safety; and coaling, loading, or unloading, etc., proceed unchecked. In many other ways economy and speed of working are promoted.

Pumping.—Mechanical power is now universally employed for pumping purposes in steamships. A few hand-pumps may be fitted, but they are used only in exceptional circumstances or for special work. Steam-driven pumps are generally preferred. Pumps driven by electric motors are now coming into use. For the ordinary service of ships ample pumping power is provided. In merchant ships where water ballast is very commonly used with economical results, the pumping arrangements are specially arranged for rapidly clearing the ballast tanks. Oil-carrying steamers have very powerful pumps for dealing with their liquid cargoes.

While ample pumping power is desirable and of service in many circumstances, it is now generally agreed that the best protection against foundering is good water-tight subdivision of the hold space. The undue development of pumping power, with a view to dealing with serious injuries from grounding or collision, is admitted to be undesirable since it is hopeless to attempt to meet a serious leak by pumping when there is free communication with the sea.

Lifting Appliances.—In no department has the equipment of modern ships received greater development than in that of lifting appliances. One of the most marked tendencies in recent construction has been increase in the size and carrying power of ships. Unless there had been a corresponding development in the means of dealing with cargo this increase of size could hardly have occurred, and the advantages resulting from that increase would not have been realised. It is a principle in ship-designing that as ships increase in size the expenditure of power and fuel for a given speed becomes relatively less, and the "useful displacement" or "carrying power" becomes relatively greater. In other words, as far as sea transit is concerned, the ratio of earnings to expenses in the larger ship should be greater than the corresponding ratio in the smaller. On the other hand, it is well recognised that unless there is "quick despatch" in loading and unloading cargoes, very serious diminutions of earnings must result from the longer detention in port. Hence it follows that, for the complete commercial success of the larger classes of cargo carriers, lifting appliances of the most efficient character and of ample capacity are of the greatest importance. The prevision of the shipowner, in collecting the cargo and having it ready to load, would be ineffective unless the mechanical appliances were adequate.

Remarkable progress has been made by mechanical engineers in meeting these demands. Certain firms have made a special study of ship-lifting appliances, and I owe the following summary of progress to my friend, Captain Chapman, the head of one of those firms. Thirty years ago most cargo steamers were fitted with hand-power crabs or winches, similar to those long used in sailing ships. Then came the fitting of engines to winches of the old pattern, the engines being placed diagonally. To reduce the strains on decks, and facilitate working and repairs, horizontal steam winches were introduced. For many years these winches had cylinders



THE MILLER CONVEYOR FOR COALING VESSELS AT SEA AS APPLIED TO THE U. S. COLLIER "MARCELLUS." INSTALLED BY THE LIDGERWOOD MFG. CO., NEW YORK

not exceeding 5 inches or 6 inches in diameter with 10-inch stroke. The lifting barrel was about 10 inches in diameter, and took the cargo chain runner. Two warping drums were fitted on the slow-speed shaft, while the quick-speed shaft carried "whipping" drums. Until twelve years ago four or five such winches formed the lifting equipment of a cargo steamer. Now in the largest steamers from twelve to twenty winches are fitted, besides cranes. Winches have cylinders from 7 inches to 10 inches. They are fitted with large barrels and outer drums on the low-speed shafts, as well as smaller drums on the quick-speed shafts. By this means five drums are made available on each winch, and by suitable arrangement of "spans" from mast to mast with falls attached, forty to fifty whips for lifting light loads may be kept going simultaneously by eight or nine winches. Steam is turned on to the winches, and they run all day, except at meal times. As a rule, light loads, say from 2 cwt. to 3 cwt., are thus dealt with. Heavier loads can, of course, be dealt with by different arrangements, say up to 6 or 7 tons.

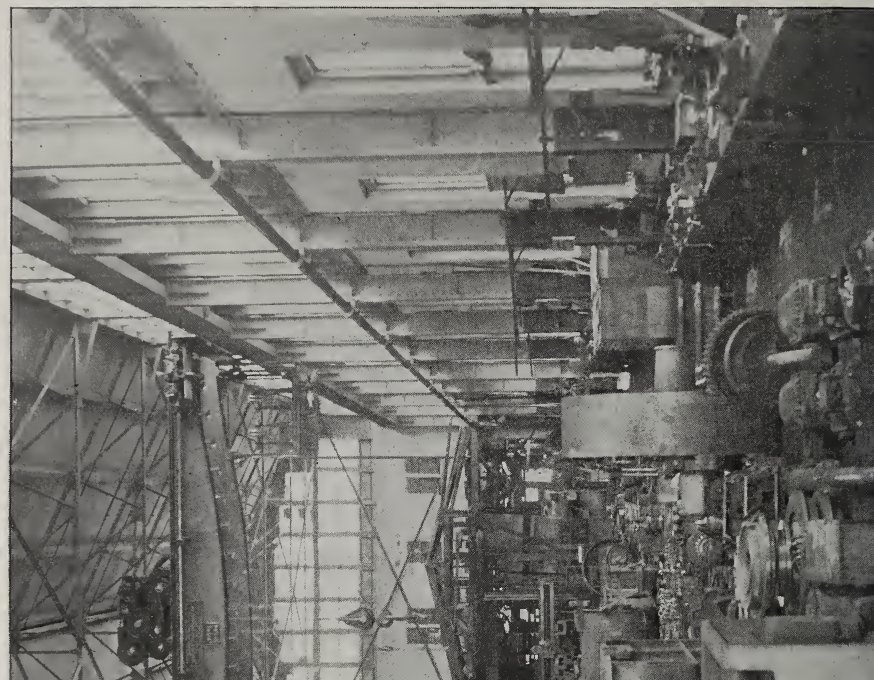
THE WHITE STAR LINE STEAMER "CYMRIC." LENGTH, 585 FEET. BEAM, 64 FEET. DISPLACEMENT, 24,000 TONS. AN EXCELLENT EXAMPLE OF A MODERN CARGO STEAMER. BUILT BY MESSRS. HARLAND & WOLFF, BELFAST, IRELAND.

Besides the winches, derricks are extensively used for lifting, being carried by the masts or by derrick posts. Cranes, standing upon the decks, are also largely used.

Great care is bestowed upon the details of all these appliances, in order to economise power and increase rapidity of working. With higher steam pressures this is a most important matter, and considerable variations of pressure have to be provided for.

Cargoes of a special character,—such as coal, ore, grain, and oil,—require to have special arrangements made for both loading and discharge. Bulky materials, such as cotton, require to be compressed into the narrowest possible limits for storage in the holds of ships. Here, again, the mechanical engineer has played an important part. It is not possible nor desirable here to dwell upon the details of coal shipping, grain elevators, ore piers and shutes, oil pumps and storage, important as these are to the successful working of many classes of ships. American engineers have undoubtedly shown the way in many directions, quickened, no doubt, by the high price of labour in the United States. British engineers have done great things also, and must not always expect to be leaders in improvement, nor should they be averse to benefiting by the work of others. In fact, they must take care that British shipowners continue to have at their command the most perfect appliances for loading and unloading cargoes.

As an example of present conditions I may present the following facts which I owe to the kindness of Mr. Thomas



THE MACHINE SHOP OF THE HARLAN & HOLLINGSWORTH CO., SHIPBUILDERS, WILMINGTON, DEL., U. S. A.

Ismay, of the White Star Line. The *Cymric* is an excellent example of a modern cargo steamer. Her measurement capacity is about 19,400 tons, her dead-weight capacity about 12,000 tons, excluding coal. Her cargo space is divided into seven holds, each of which is subdivided into three compartments, viz., 'tween decks, orlops, and lower holds. Five of these compartments are fitted as refrigerators, with a total capacity of about 2200 tons. There are nine hatchways, fifteen derricks, seventeen steam winches for cargo purposes, and masthead "spans." The capability of these appliances is illustrated by the fact that she has commenced discharging a full cargo at 7 A. M. on Monday, completed her loading of cargo and taken on board 1600 tons of coal, and undocked at noon on the following Friday. Loading and unloading were carried on to a great extent concurrently, about 400 to 450 men were employed, and the average rate of discharge was not less than 300 tons (weight) per hour, the corresponding rate of loading being about 250 tons. All the general cargo, apart from bulk grain, etc., was weighed at landing. When it is remembered that in such a general cargo there may be 30,000 to 40,000 packages to be dealt with, these results are evidence of both excellent mechanical arrangements and perfect organisation.

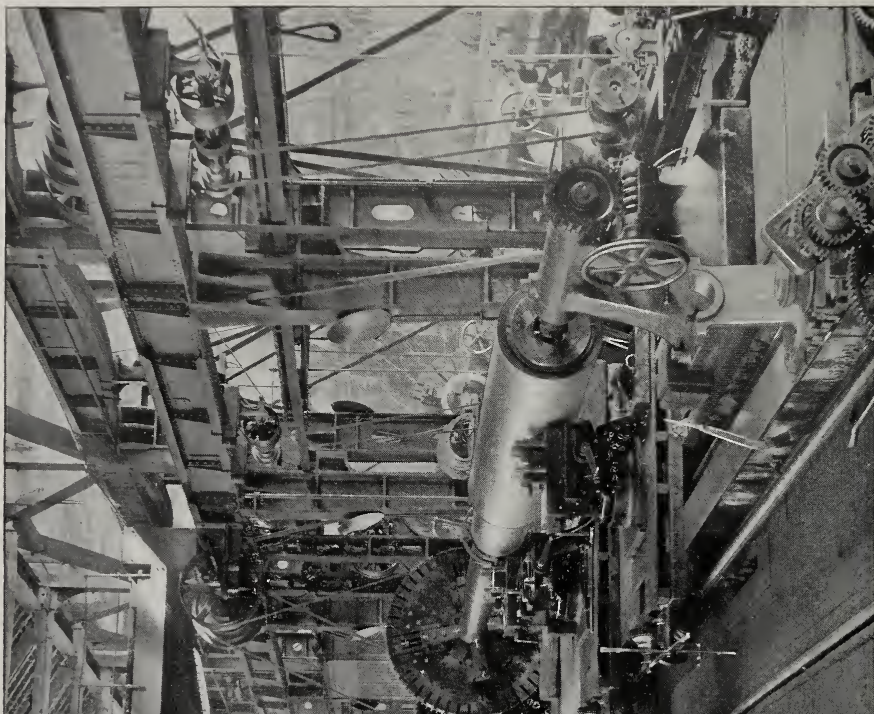
The Hamburg-American steamer *Pretoria* has fourteen powerful steam winches, eight steam cranes capable of lifting 3 tons each, and is so fitted that about forty lifts can be undertaken simultaneously.

Steam power has been principally employed hitherto for these lifting appliances. Hydraulic power has been used to a limited extent, but with complete success. Electrical power is now applied in some cases, and will probably be more extensively used in future.

Refrigeration.—This is one of the most recent, and at the same time one of the most important applications of mechanical engineering on board ship. It is not yet twenty years since the frozen meat trade was begun between Australia and England. At the outset comparatively small cargoes were carried; but as machines were improved and experience was enlarged, so larger cargoes were carried, and a new branch of the shipping industry was created. Sir Alfred Haslam, who has done so much to develop this branch of mechanical engineering, has at my request given me some interesting facts. The first refrigerators were designed to deal with 150 tons of meat. Now machines are constructed capable of dealing with 3000 tons, while they occupy only two-and-a-half times the space, and consume about three times the coal required for the first machines. In 1881 about 14,000 carcases were brought to Great Britain from the Colonies; in 1899 it is anticipated that from 18 to 19 millions will be delivered from the Colonies and various parts of the world. In addition to dead meat, large quantities of butter, fruit, and other perishable cargoes are now carried from the far ends of the earth and delivered in good condition.

Space does not permit me even to touch upon the relative merits of various types of refrigerating machines. Cold-air machines were first used and still find favour for use on board ship. Ammonia compression machines and other chemical machines are also used. Nor do I more than allude to the enormous scale on which cold storage on shore has grown. The first stores at the London Docks held about 400 tons of meat, or 1600 carcases. Stores now being completed at the Victoria Docks will hold about a million carcases. The first refrigerating machine used in connection with these stores in 1880 was equivalent to the melting of 21 tons of ice in 24 hours. A machine is now in construction which has about tenfold as great a power.

All who travel by sea know how much health and comfort are promoted by the change in dietary made possible by refrigeration. In recent years refrigerating chambers have become a part of the equipment of the larger classes of ships in the Royal Navy. Two machines are usually fitted, each of which has to be capable of reducing the temperature of a chamber of 1800 cubic feet capacity



A SHOP INTERIOR AT THE ELSWICK WORKS. SIR WM. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE ON-TYNE

to 15 deg. F., and of easily maintaining that temperature when the temperature of the atmosphere and sea-water are at 100 deg F. and 85 deg. F., respectively. The atmosphere in the chamber must also be kept perfectly dry.

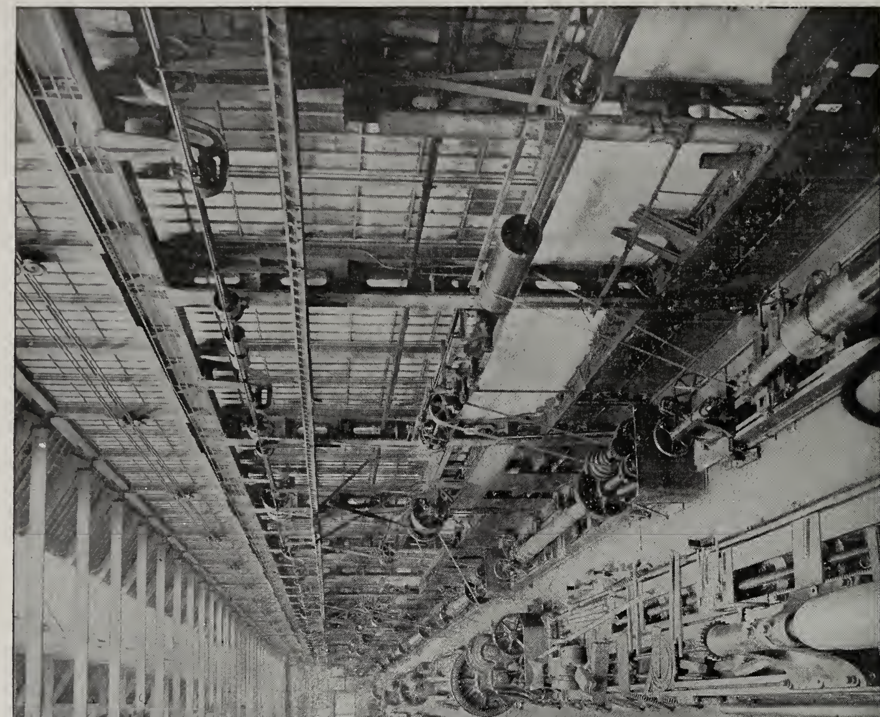
Auxiliary Machinery on Warships.—The auxiliary machinery of warships necessarily has much in common with the corresponding machinery in merchant ships. There are, however, many special requirements arising from their armament and equipment as fighting machines, and hence it happpens that in warships the applications of mechanical power reach their fullest development. Modern warships are sometimes styled "boxes of machinery," and the description is not inapt. The tendency is, in fact, to multiply machines, and to minimise manual labour to an extent which is not universally approved. On the other hand, with modern armaments and equipment, an extensive use of mechanical power is inevitable, and the expenditure of fuel on auxiliary services grows greater in proportion to that devoted to propulsion.

Ten years ago, in a first-class battleship of 12,000 horse-power (maximum) for the propelling machinery, there were fifty auxiliary engines capable of indicating in the aggregate about 5000 horse-power if they all worked simultaneously, which they did not, of course. To-day a similar statement would show a growth in the auxiliary power as compared with the propelling.

The multiplication of auxiliary services makes very serious demands upon the coal supply of warships. Even in harbour the expenditure of coal is large on lighting, distilling, ventilation, air-compression, drilling with the heavy guns, and other services. From 10 to 25 tons a day may thus be expended in a large battleship or cruiser of high speed. As warships cruise at low speeds, and spend much time in harbour, it results that, taking the year through, fully as much coal is burnt for auxiliary services as for propulsion. Coal endurance being one of the most important factors in warship efficiency, facts such as these have tended to cause a doubt as to the wisdom of more widely extending mechanical appliances. It is pointed out that manual power with simple fittings, such as can be readily replaced if damaged in action, can compete with mechanical appliances in many directions; and that it is better to have larger crews in fighting ships, so as to provide a margin for inevitable casualties, than to use the alternative of labour-saving machines liable to derangement or injury and not easily repaired in action. The practical solution of the problem clearly lies in the due proportion being found between manual and mechanical appliances.

Gun construction in its modern form is largely dependent upon mechanical engineering. Lord Armstrong and the late Sir Joseph Whitworth were famous as mechanical engineers before they undertook the design and manufacture of guns. In this address, however, the story of progress from the smooth-bore cast-iron 68-pounder, weighing 95 cwt., to the 110-ton breechloading rifled gun, firing 1800-pound projectiles, can find no place. Nor can more than a brief glance be taken at the interesting work done by the mechanical engineer in regard to appliances for mounting, working, and loading modern guns, supplying the ammunition, and securing rapidity and accuracy of fire with a minimum of labour.

Any one who will study the breech mechanism and mounting of a hand-worked quick-firing gun will discover a triumph of mechanical engineering over a very special and difficult problem. Take for an example a 6-inch quick-firing gun of the latest naval pattern. The gun weighs about 7 tons, fires 100-pound projectiles with muzzle velocity of nearly 2800 feet per second, and an energy of 5370 foot-tons, corresponding to a penetration of 22 inches of wrought iron. Its breech mechanism is so devised that four or five aimed shots can be fired per minute. Its mounting is so arranged that the gun can be easily trained, elevated, or depressed by one man. The great energy of recoil is perfectly controlled, and the crew numbers only four or five men. If such a



ANOTHER ELSWICK SHOP VIEW

gun is compared with the 68-pounder smooth-bore muzzle-loader, mounted on a wood truck carriage with rude arrangements for elevating, and still ruder for training and controlling recoil, one has a striking illustration of the progress made in forty years with hand-worked guns.

When one passes to heavier guns worked by mechanical power a still greater contrast appears. The 110-ton gun of 16¼-inch calibre has charges of 960 pounds of powder and 1800-pound projectiles. Fired with a velocity of 2100 feet per second, these projectiles have an energy of 54,000 foot-tons, with an estimated penetration of 37 inches of wrought iron. Obviously, manual power alone was unequal to working such guns. The mechanical engineer has devised suitable machinery which enables pairs of guns, mounted in a thickly armoured turret, to be loaded, trained, elevated, and depressed with ease and comparative rapidity under the guidance of a few men. Mr. George Rendel was one of the first, as well as one of the most successful, workers in the design of mechanical appliances for working heavy guns by hydraulic power. Messrs. Armstrong have from the first taken a leading position in this class of work. Messrs. Whitworth, and in more recent times, Messrs. Vickers, have also undertaken it on a large scale. Hydraulic power finds most favour in the Royal Navy. Abroad electrical power is now extensively used. Pneumatic power has been employed in a few cases.

Improvements in gun design and in explosives have resulted in an increased ratio of power to weight in the latest types of guns. As a result, in the latest completed battleships, guns of 12-inch calibre, weighing 46 tons, firing 850-pound projectiles, with muzzle velocities of about 2400 feet per second, and energies of 33,000 foot-tons, have been used instead of the 67-ton and 110-ton guns of earlier date. These reduced weights of charges and projectiles are more easily handled; and this fact, together with certain changes in the system of mounting, have enabled many of the operations of loading and working the guns to be performed by manual power as well as by hydraulic power. This duplication is obviously advantageous, and reduces greatly the risk of heavy guns being put out of action. There was a time when a return to guns of still smaller dimensions, capable of being worked exclusively by hand-power, was strongly advocated. It was urged that it was unwise to depend at all on mechanical power because it might fail at a critical moment. Such arguments are now but little heard. Experience does not demonstrate that any serious risk of "breakdown" need be feared in mechanical appliances. Moreover, the advocates of manual power overlooked the fact that, supposing that system had been adopted, there must still remain in all modern mountings and breech mechanisms many comparatively delicate parts, perhaps more liable to injury or derangement than the appliances which were condemned.

Steady improvement has been made in heavy gun mountings and in rapidity of fire. For example, with 12-inch guns from two-and-a-half to three minutes were formerly considered to be a reasonable interval between successive rounds; now that interval has been brought below one minute, when pairs of guns are loaded and fired. Loading has also been made possible with the guns in any position, whereas formerly the guns were brought to fixed hoists, and to a definite angle of elevation for loading. It is most interesting to watch the working of these heavy guns, by means of mechanisms controlled by a few men. All the operations are performed with rapidity and precision from the moment projectiles and charges are moved from their stowing positions in shell rooms and magazines situated deep down in the holds, up to the time when they are rammed home in the gun, the breech is closed, and the gun made ready for firing. Then one sees the captain of the barbette or turret training or changing the elevation of the gun up to the instant when he fires by electricity, and the huge projectile is discharged.

Passing from guns to torpedoes, one finds a fresh example of the important

work done by mechanical engineers. The inventor of the automobile torpedo, —Mr. Whitehead,—is an eminent member of the profession. The torpedo itself is a beautiful example of mechanical engineering. All the machinery connected with air compression and storage, all the arrangements for ejecting above or below water, involve skilful mechanical design. Nor is this all. From the introduction of the torpedo has sprung the necessity for special structural and defensive arrangements in warships, as well as the construction of the swift torpedo flotilla boats, destroyers, gunboats, and dépôt ships whose performances are not merely remarkable, but suggestive of possibilities in regard to steam navigation at high speeds.

The smaller classes of boats using the locomotive torpedo have to be carried by warships. They weigh, fully equipped, 18 to 20 tons, or about three times as much as the heaviest load ordinarily dealt with in merchant ships by their own lifting gear. This has involved the design of special lifting appliances for warships. After long experience in the Royal Navy the most suitable arrangement has been found to be a strong steel derrick carried by the mast, with powerful steam or hydraulic hoists working tackles which lift the boats and top the derrick. Winches or capstans are also used in some instances for swinging the derricks. Admiralty specifications require that the lifting gear shall be capable of dealing with a load of about 18 tons lifted by a single wire rope, as well as with a load of 9 tons raised 30 feet per minute. In one ship, the *Vulcan*, built as a torpedo dépôt ship and boat carrier, instead of derricks two powerful hydraulic cranes are fitted. She carries six steel torpedo-boats 60 feet long and of 16 knots speed, besides sixteen other boats, some of large size. The total weight of these boats is 150 tons, and they are placed 27 feet above water. The two cranes and their gear weigh 140 tons; the tops of the cranes are 55 feet above water.

Besides these special boat-lifting appliances warships commonly have special coal hoists, transporters, and other gear for the purpose of accelerating the taking of coal on board. Rapidity in coaling must be of great importance in time of war, and keen competition between ships in the various squadrons as to the rates attained, have led to great improvements in details of gear, as well as to remarkably rapid coaling becoming the rule in the Royal Navy.

All the larger ships in the Royal Navy have engineers' workshops fitted with a considerable number of machine-tools, driven by power, and of sufficient size to deal with ordinary repairs. The *Vulcan* is a special vessel in this sense also, as she has an exceptionally well-equipped workshop, a small foundry, and an hydraulic press for forgings. For the repairs of the boats she carries, or for those of torpedo-boats and destroyers in company, or for certain repairs to ships of the fleet to which she is attached, the *Vulcan* has been found most useful. Besides being a floating factory and a boat carrier, she has a large torpedo and mining equipment, an electrical laboratory, and serves as a school of instruction for mining and torpedo work. In addition, she is a swift cruiser, with a fair armament and well protected. Another *Vulcan* was fitted up as a floating factory to serve with the American fleet during the recent war. She was originally a merchant steamer, but proved of great service. Naval opinion seems to favour the use of vessels of this class with fleets. It is held, moreover, that no modern fleet can be considered to be complete unless the fighting ships are supplemented by ships specially equipped for distilling and storing fresh water, or carrying coals, ammunition, and reserve stores.

This rapid review has much exceeded the limits I desired to impose, but even now it is very imperfect and incomplete. Enough has been said, however, to place beyond doubt the correctness of my preliminary statement, that the alliance of the shipbuilder and mechanical engineer has been of immense practical advantage to shipping interests.

PRACTICAL LIMITATIONS OF ELECTRIC POWER TRANSMISSION

By Dr. Louis Bell

WHEN a new art is thrust upon public attention, the first sentiment awakened is general incredulity. And when the thing which was pronounced impossible has been accomplished and the consequent feeling of irritation has subsided, there often follows a period of extreme credulity, when the wildest claims are eagerly believed and the most improbable feats almost taken for granted. It is prudent, therefore, in the hour of determinate success to take thought for the future and to endeavour to discern the limitations that, sooner or later, are bound to be encountered.

During the past seven or eight years the electrical transmission of power over considerable distances and at high voltage has grown from dubious experiment to commercial success upon the largest scale. Plants doing such work are now numbered by the score, almost by the hundred, and the art has reached that stage of its development where to look ahead is a desirable precaution. Over-confidence is nearly, or quite, as bad as over-cautiousness.

The writer is going, therefore, to discuss here some of the engineering and commercial difficulties with which one has to deal in extending the scope of electric power transmission beyond the practice that is now obviously successful. Some of the obstacles will, doubtless, be removed as improvements go on, and some will change with changing conditions, but nevertheless they must be considered. The most fundamental present question is the limit of practicable voltage. Since the cost of copper for the transmission line varies inversely as the square of the working voltage, the commercial feasibility of long-distance working is directly involved in this question, as well as matters of great theoretical interest.

During the past half-dozen years a great fund of practical information has accumulated as to transmission at high voltage, and within a wide range engineers are now treading on no uncertain ground. Steadily what might be called conservative voltages have been creeping upward, and experiment has grown into standard practice, until the art has been revolutionised. The first great step was taken when engineers squarely faced the problem of dealing with alternating currents at pressures that needed to be treated with respect, and came to a realising sense that the proper place to insulate a high-tension wire was at its supports. It very soon became evident that, once past pressures that can be handled with impunity, a further increase involved no material additional danger to life or property, and was practically limited only by existing conditions as to insulating the apparatus. Given adequate insulation at the supports, the line problem was, and is, easy, and included only trivial dangers and difficulties in passing from two or three thousand volts to eight or ten thousand.

The upshot of the matter has been that the one thousand-volt plants common ten years ago are now practically obsolete even for local distribution, while

for transmissions of even a few miles five or ten thousand volts represent the usual figure, the latter more often than the former. Just at this point is encountered a limitation in apparatus, or perhaps methods, which cannot be overlooked. It is not yet possible to procure standard transformers of the sizes customarily used for electrical distribution for a primary voltage higher than 2400 or 2500 volts. This fact compels the use of reducing transformers if it becomes desirable to use higher pressure for the transmission, and once these are installed, it is plain economy to lift the line pressure as high as practicable.

At the present time one may fairly call 10,000 volts the standard working pressure for transmission purposes. It has proved entirely feasible to properly insulate currents at this pressure under the severest weather conditions, and enough plants have been running for considerable periods to prove beyond question that they are in every way as reliable as if worked at much lower pressure. So far, so good; but how much further can we go?

As the voltage climbs beyond this figure no alarming phenomena appear for some time. The danger of puncturing insulators increases, but this merely makes it necessary to thoroughly test them and to provide a suitable factor of safety. Raising and reducing transformers are not rendered materially more difficult and expensive to insulate.

The "striking distance," however, rises noticeably. By this is meant the distance over which a spark will spontaneously jump under the pressure involved. It really measures the dielectric strength of the air, and depends greatly on the forms and dimensions of the things between which there is opportunity for sparking. A given difference in pressure will jump a spark much further between points than between balls or flat surfaces. For example, 10,000 volts will leap barely 1/8 inch between balls an inch or two in diameter, but about 15/32 inch between the points of common sewing needles.

This increase of striking distance is a matter that is not yet troublesome except as it may indicate resonance. Resonance, electrically, is substantially the same sort of thing that it is in acoustics, —a strengthening of the intensity, *i. e.*, voltage, of certain vibrations when they are in tune with things subject to the same vibrations,—electrically, in circuit with them. An alternating current involves electrical oscillations as complex as the vibrations of a violin string, and the resonance may take place with the main vibration period,—the fundamental,—or with any of the harmonics. Electrical resonance with the fundamental periodicity is rare,—very rare, in fact; but the minor sort of resonance, with the higher harmonics, is probably far more common than is usually supposed. To it is frequently due the considerable increase of striking distance often noticed on long lines, which sometimes may become annoying, but seldom serious.

Aside from this there is little noteworthy as the pressure is raised until one nears 20,000 volts. At about that point the lines begin to be luminous at night,—at first a hazy bluish film of light at the surface of the wires, with faint brushes at the points of tie wires and the like. The writer saw the same sort of thing recently for several inches along the edge of a bit of dry asbestos paper that accidentally touched two 10,000-volt cables insulated with rubber a quarter of an inch thick. Here, then, is a new factor in the case,—a static discharge into, and through, the air along the high-voltage wires. The energy is leaking off wherever it gets a chance,—from the wires, across the oil in the transformers, from every point or edge along the line.

At 20,000 volts this static leakage amounts to very little, in fact, it is merely visible, and a growing group of plants working steadily at that pressure bears evidence that there is little to be feared, at least in ordinary climates. As the voltage rises above this point, the air discharge becomes more marked, until at 40,000 volts a very perceptible amount of energy, though not a material amount, is devoted to keeping up this action. It is exactly the same sort

of thing that one sees in a darkened room about the wires leading from a powerful Ruhmkorff coil, except that it is on a colossal scale, with perhaps a thousand-kilowatt generator behind it instead of a few battery cells. Add 10,000 or 15,000 volts more, and the situation becomes serious,—the energy streams off in amounts rapidly growing graver, and under the terrific strain the air tends to become weaker and weaker as an insulator.

At this point two courses are open, either to increase the distance between wires or to insulate them. The latter course probably cannot afford permanent relief and the former mitigates the evil, but does not altogether cure it. Hence, although one plant is in regular and quite successful operation at 40,000 volts, it seems that we are at this point nearing a limitation due, not to an imperfection in our methods, but inherent in the medium in which we are working. Between 50,000 and 60,000 volts the case grows very serious, perhaps prohibitively so, as long as we attempt to work overhead in air.

Underground, or above it in oil tubes? Possibly, when some one finds a cheap non-conductor that will hold oil successfully; but even then resonance is to be dreaded. Going underground or into tubes means adding capacity to the system and this means a chance of hitting resonance of lower harmonics or even the fundamental. Very formidable resonance has been detected on one line having some underground connections, and we shall hear more of it, although it is worth noting that increased voltage does not necessarily imply increased danger of resonance. In point of voltage, then, we must look out for trouble in going above 30,000 to 40,000 volts, even in a good climate, and if we go underground we must be very cautious about it. And, to a certain extent, we are between the devil and the deep sea, for if there is resonance underground, lightning lies in wait for us overhead.

No problem in power transmission work needs more careful attention than lightning protection. Most good lighting narresters work well most of the time, and that is about all one can say for them. In operating at 10,000 volts or more, the striking distance, often reinforced by minor resonance, is great enough to call for considerable air gaps at the lightning arresters in order to prevent constant striking across. Hence, there is a pretty stiff strain on the insulation of the apparatus, and the additional force of even a moderate lightning discharge may lead to serious results. Trouble of this kind seldom leads to material interruption of the service or to great damage, but it is often very annoying.

Protective apparatus successful in one plant sometimes fails in another without apparent reason, and the best results require considerable study in each individual case. These difficulties, however, one cannot fairly regard as more than temporary, since they will, in all probability, yield to improved methods of attack.

Bearing in mind the present appearance of limitations in voltage, the next important question that arises is that of maximum feasible distance of transmission. Here both the technical and the commercial limitations must be taken into account. As regards the former, present experience runs up to a little over a hundred miles,—eighty miles on a large commercial scale. The net result of this experience is to show that up to these distances no special difficulties are to be feared, the longest lines behaving, in all important respects, just like the shorter ones. Barring malicious interruption, such as the shooting off of an insulator, the longer lines are no less reliable and no more difficult to keep in good working condition if properly put up. It should be borne in mind that a transmission line, usually constructed with heavy insulators and good-sized bare wire, is unlikely to come to grief except by unusual external violence. As a matter of experience, storms produce almost no direct damage on such lines. The writer knows of no instance of a transmission line going down or suffering serious damage from pure violence of weather. Now and then a branch of a tree may be blown down across the

wires, but as far as practicable such lines are run in clear country, and elsewhere the trees are likely to get gradually cleared away so as to avert any such danger.

Given a well-built line and proper inspection, and mere distance, so far as yet ascertained, involves no serious problems. At distances much in excess of a hundred miles it may be found desirable to lower the frequency of the currents employed, but so far as engineering difficulties are concerned there is no reason why a transmission of even five hundred miles could not now be successfully undertaken.

Commercially, the case is different. So long a line would not be undertaken except for the transmission of a very large amount of power, and the mere cost of the line, even at a working pressure of 40,000 volts or so, would be a formidable item. There are few, if any, instances in which, from low cost of power or high selling price at the market, such an expenditure would be justified. The writer recalls one case being brought to him in which a transmission of 200 miles gave good promise of paying, for coal was $50 (£10) per ton in gold at the terminus, but the fall in the price of silver kept the project from being carried out. Success was merely a question of proper care of the line.

To get and keep a line clear of mechanical interference is more than half of the battle in all power transmission work. Poles and cross-arms should be strong and well put up, insulators carefully inspected and tested, if necessary, and the way cleared as far as possible of obstructions. Generally speaking, crossing other lines should be avoided, and the transmission wires should be kept out from under telephone and telegraph wires so far as practicable. As a matter of fact, nineteen-twentieths of all accidents from high voltage circuits are due to these lighter and weaker wires falling upon them.

Broadly, one may sum up the engineering side of the whole matter by saying that, at present, voltages from 10,000 to 40,000 are being worked successfully, the former being well-tried and conservative, the latter somewhat experimental as yet, and verging upon conditions that become troublesome not far beyond that limit; that up to fully a hundred miles in distance no limitations are encountered at customary voltages and frequencies other than those due to increased length of line to be protected; and that at still greater distances there are no troubles in sight which good design and careful construction cannot overcome.

Commercially, the limitations of successful power transmission are more circumscribed. Theory here fails to throw much light on the subject. The whole matter hinges on the cost of hydraulic rights and their electrical development on the one hand, and the cost of locally generated power on the other. Generalising becomes, then, the result of examining a large number of concrete cases. Taking these as they come, it is within bounds to say that, considering transmissions of 500 or 1000 kilowatts, nearly all those at distances no greater than 15 to 25 miles will pay, if the output can be marketed. From 25 to 50 miles many will pay, but the circumstances must be rather favourable. From 50 to 100 miles a few large enterprises under good conditions will succeed, while many will be of dubious value; and beyond 100 miles cases of probable or certain success are rare, but assuredly they do exist. These limitations are necessarily rough, but they express the facts as we have them today.

As we get to working higher and higher voltages at longer and longer distances the electrical phenomena most likely to cause trouble are those connected with electrical capacity, chiefly resonance, and lightning. To get these under control, a good bit of hard study and experimentation will be necessary, but the task is by no means hopeless. For working out the matter practically, a transmission of a thousand or two kilowatts over 150 to 200 miles in a favourable climate is a step greatly to be desired. Such a transmission is certainly feasible, and would pay under good local conditions, while it is far enough out-

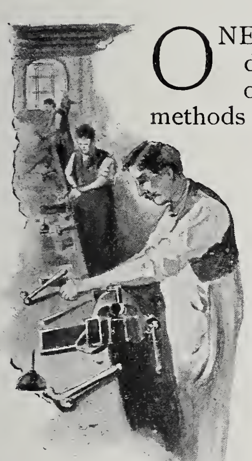
side of present experience to afford valuable lessons upon further extensions of practice.

Such a case will probably arise, in the natural course of events, before long, and as it offers no great difficulties it can be confidently undertaken. Then the way will be cleared for a good space ahead and we shall know what real importance to attach to many considerations that are now of doubtful issue. Many things can be accomplished as feats of engineering that are not of commercial importance, and work upon a large scale is necessary to show the whole problem in its true perspective. The carrying out of such experiments has a vital interest far beyond the mere utilisation of distant water powers. It may, and very possibly will, open up the way for the wholesale transmission and distribution of power from coal fields,—a side of the matter hitherto untouched, except speculatively upon paper. The nineteenth century has not seen it, but the twentieth century may, and much more besides, now invisible in the haze that can be pierced only by skilfully planned and daring enterprise.

FACTORY HEATING

BY A FORCED CIRCULATION OF WARM AIR

By Walter B. Snow



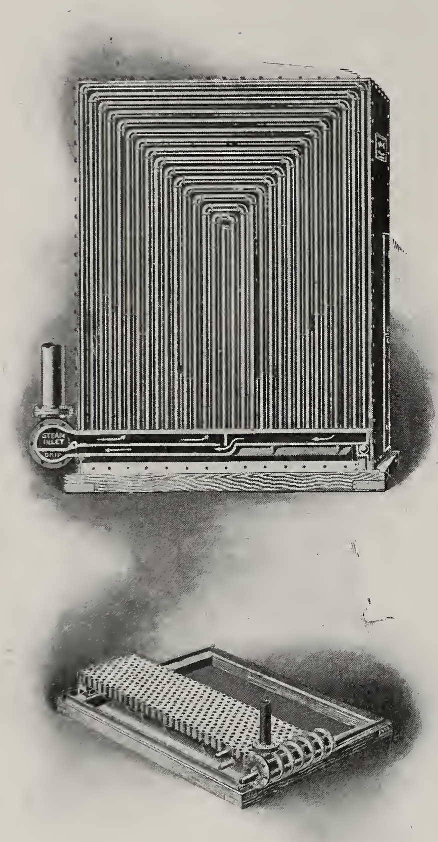
ONE of the marked evidences of the refinement of modern manufacturing methods is to be found in the increasing care taken to secure the utmost comfort for the employees. Humanitarian as this effort appears, there is a mercenary strain running through it, notwithstanding, for it is acknowledged that the best work in the greatest amount can be secured only under the most suitable conditions of environment. Along with the provision of good light, ample space and healthful sanitary arrangements, much thought has been devoted to securing the best means of warming and of maintaining a healthful atmosphere within the factory. Naturally the problem of ventilation becomes more serious in proportion to the increase in vitiation due to the processes of manufacture.

We have seen the stove superseded by methods of direct heating, and are now witnessing a further advance by the substitution of a combined system of heating and ventilating by means of a forced circulation of warm air. This method, which is here the subject of discussion, is familiarly known as the fan or blower system, and comprises these elements:—a fan or blower; a heater; and a system of distributing ducts or pipes, more or less extended according to the conditions. In ordinary practice the fan is of the centrifugal type, encased in a steel plate housing, and usually arranged to draw air through a steam heating coil with pipes closely spaced. From the fan the air is forced to the desired points within the building. The air thus becomes a vehicle of heat, serving to accomplish all of the results incident to the use of direct heating surface, and at the same time meeting the requirements of good ventilation.

When heating is accomplished by direct radiation with steam pipes strung along the walls, the wall itself adjacent to the heating surface is maintained at high temperature, so that the temperature difference between it and the external air is great, and rapid transmis-

sion of heat results. With an overhead arrangement of piping the loss is less, but nevertheless of considerable magnitude.

Air is a very poor absorbent of radiant heat, and is readily warmed only by direct contact with the heating surface. With the low velocities resulting from the natural circulation of air across such surfaces the hourly condensation per square foot of surface with low pressure steam is only about three-tenths of a pound of steam, equivalent to about 1.8 British thermal units per square foot per hour per degree difference between the temperature of the steam and the air.



A STANDARD FORM OF HEATER

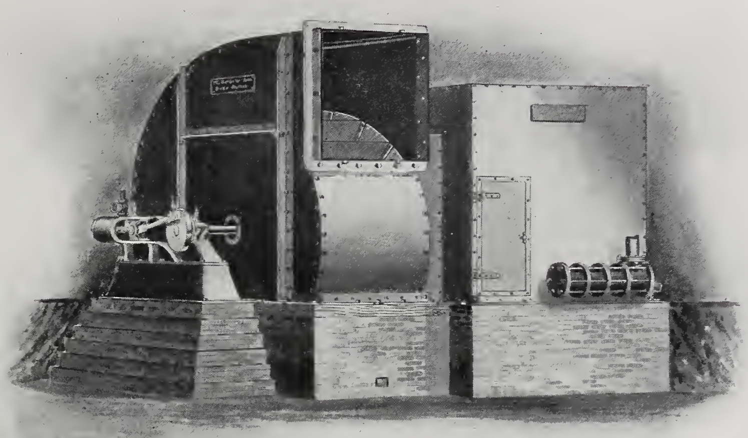
As the velocity of the air across the pipes increases, so does the rate of condensation and of heat transmission. Within the ordinary limits of practice this increase appears to be in proportion to the square root of the velocity of the air. It is, therefore, evident that the heating surface required to transmit a given number of thermal units may be decreased in proportion as the velocity, and consequent volume, of air passing across the surface are increased.

In the ordinary hot blast apparatus, such as is employed in the fan system, the heating surface is massed in one location, a decided contrast to the almost unlimited extent of pipe required where a direct heating system is employed. This massed surface is usually made up in sections, each consisting of a cast-iron base with suitable partitions therein, so that the steam, admitted through one end, passes up, over, and down a series of steam pipes, and finally escapes in the form of water of condensation from the chamber below. In the best types of hot blast heaters the pipes are one inch in diameter, placed 2⅛ inches on centres, and arranged with either two or four rows to the section. The pipes are staggered, thereby providing tortuous passages for the air, with constantly changing exposures and intimate contact.

These sections may be bolted up together in groups, the heating effect with constant air velocity being proportional to the depth of the heater. This proportion, however, is not direct, but constantly decreasing, owing to the lessening difference between the temperature of the air and that of the steam within the coil. The free area for passage of air between the pipes is generally about 40 per cent. of the gross area of the face of one of these sections, and the velocity through this free area approximates 1800 feet per minute in factory heating.

The compactness of such a heater is evident from the fact that a mile of one-inch pipe can be put into a space that measures but little more than 3 feet by 6 feet by 7 feet. The maximum condensation secured under these conditions may run up to three pounds per square foot per hour with high-pressure steam, but is, of course, dependent upon the temperature and velocity of the entering air, the pressure of the steam,

and the manner of arrangement of the heating surface. The more rows of pipe across which the air must pass, the higher the resultant temperature, and the less the total average transmission

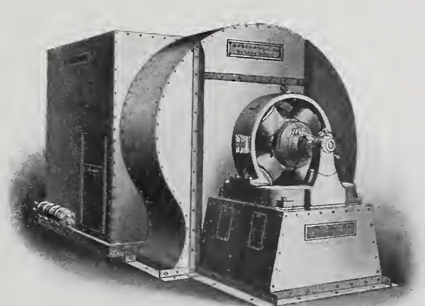


A THREE QUARTER HOUSING TYPE FAN AND HEATER BUILT BY THE B. F. STURTEVANT COMPANY, BOSTON, U. S. A.

per unit of surface for the entire heater. A fair average is about 10 British thermal units per square foot per hour per degree difference of temperature. In fact, the area of surface is only one-third to one-fifth that required with direct radiation.

This entire heating surface, properly connected up with supply and drip, is enclosed in a steel-plate casing, connecting either with the inlet or outlet of the fan, usually the former. The air is thus drawn through the heater, and passes through the fan at a temperature ranging, in ordinary practice, from 125 to 150 degrees Fahr. The localised and enclosed feature of this surface eliminates the constant danger of freezing, and of damage from leakage as well as from fire where high-pressure steam without proper insulation is employed, which is incident to the employment of direct heating methods. Insurance rates may thus be reduced and convenience secured in the control of the temperature within the building.

The fan, which is of the ordinary centrifugal type, operates by admission of air at the inlet in one side, and by its delivery at the circumference into the enclosing steel plate case, the outer circumference of which is of the nature of



AN ELECTRICALLY DRIVEN FAN

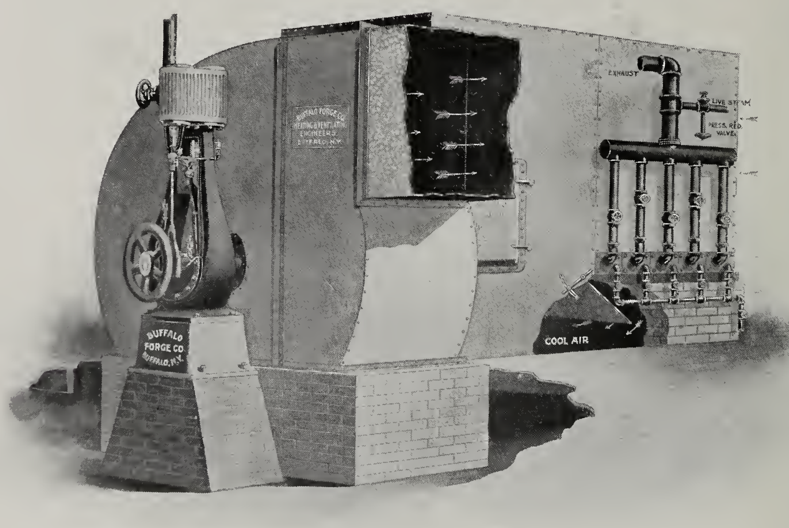
a scroll, increasing in radius toward the outlet, thereby providing space for the passage of air, and decreasing the re-

sistance. For factory heating the tip speed of the fan wheel is about one mile per minute with a resultant air velocity through the outlet ranging from 3000 to 3500 feet per minute.

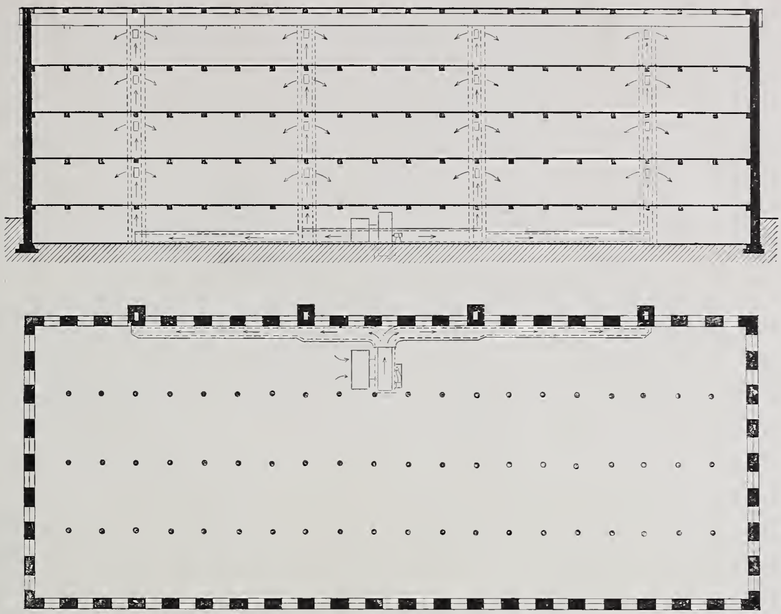
The design of the fan must depend largely upon the conditions. As usually constructed, it may be arranged to discharge in any given direction, and may be built either with a full casing or with a portion of the scroll formed in the brick foundation. It is then known as of the three-quarter housing type. The most convenient arrangement consists in providing a direct-connected engine or electric motor, whose sole duty is to operate the fan. It is thus rendered independent of any other source of power, and may be started up at any time. This is particularly desirable in the matter of heating up in the morning, or for continuous operation during the night.

From the fan outlet the air may be conducted by galvanised iron pipes or brick ducts to its proper destination. In the simplest type of manufacturing building, like an open boiler shop or foundry, the best results can be secured by extending the pipe overhead and entirely round the interior of the building, providing outlets at regular intervals so that the air may be discharged slightly downward, and toward the outer walls. A relatively warm barrier of air is thus created close to the exterior of the building, serving to prevent direct effects from the cool walls, and securing both ample circulation and ventilation. The pressure maintained by the fan is sufficient to cause the leakage to be outward, thereby avoiding objectionable draughts at cracks and crevices.

In the location of such an apparatus consideration must be given to the accessibility of the steam supply. Frequently the apparatus, if placed above head level, not only leaves the floor space free, but provides for the gravity return of the drip. The ordinary type of heater is designed for the utilisation of exhaust steam, and may be so subdivided that, if necessary in cold weather, additional heating power may be secured by admitting high-pressure steam to one or more sections across which the air of highest temperature passes. The actual cost of operation of an engine-driven fan is very slight, for the exhaust steam can be utilised in the heater, one section of which is usually arranged for this pur-



A FAN AND HEATER BUILT BY THE BUFFALO FORGE COMPANY, BUFFALO, N. Y., U. S. A.



SECTIONAL ELEVATION AND PLAN OF A FACTORY WITH EXTERNAL PILASTER FLUES FOR WARM AIR SUPPLY

pose. In many classes of manufacturing buildings it is possible, because of the high velocity of the discharged air, to eliminate a large proportion of the distributing pipe, and force the air for considerable distances. Special opportunity is provided where the occupants are actively engaged, and where slight air currents would not be objectionable.

In the ordinary hot-air piping system, allowance is made at all turns and branches for the resistances thereby imposed, and, as a rule, the aggregate areas of the outlets will range from 25 per cent. to 40 per cent. in excess of the area of the outlet of the fan. This brings the corresponding velocities of discharge down to 2800 or 2500 feet per minute, or even lower where the resistances are great.

According to the character of the building and the conditions existing within it, the entire air supply may be taken from out-of-doors, thereby providing the most ample ventilation, or, during the coldest weather, may be returned from the building itself in such proportion as desired, and continuously reheated. Even under this arrangement, the natural leakage is so great as to bring about a frequent and complete change of air within the building, providing ample ventilation.

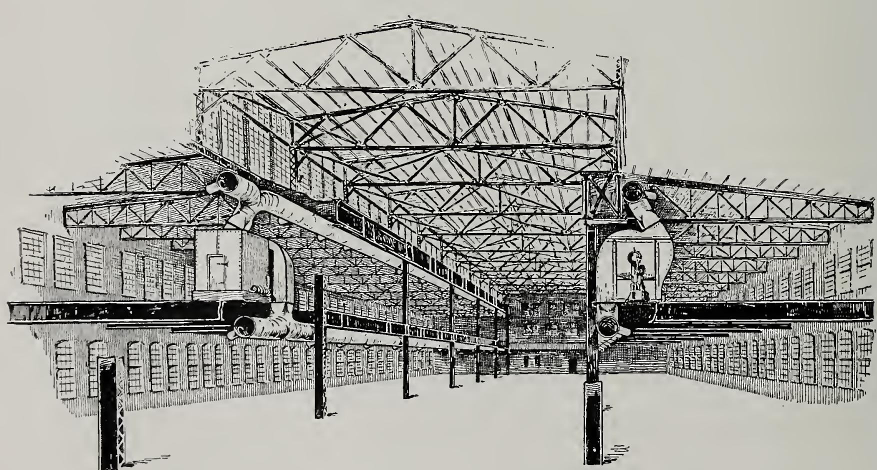
In comparing the relative operating expenses of a direct heating system with one of the character under consideration, account must be taken of the natural percolation of the air through the walls and crevices of any ordinary structure. This is so great as to frequently represent, even with a direct heating system, a complete change of air once in half an hour. This leakage, of course, adds just so much to the expense of heating, for all of the air thus entering must be warmed to the temperature of the room, and a corresponding amount must escape. Other things being equal, the expenditure of heat for mere warming remains constant, for it is dependent solely upon the difference between internal and external temperatures.

If the heating medium be hot air, the best method of regulating the internal temperature is by supplying the air in constant volume, but at different temperatures, according to the requirements

of the various rooms. This may be done by placing supplementary steam heaters in the ducts to the rooms. Where the rooms are small, this arrangement is likely to introduce unnecessary complications, and it is much simpler to maintain a diversity of internal temperature by regulation of the air supply only.

THE BLOWER SYSTEM IN A BOILER SHOP

With the fan or blower system it will be found that to maintain a temperature of 70 degrees with the outdoor temperature at zero, a change of air every sixteen minutes with an entering temperature of about 140 degrees will represent a fair average. Under these circumstances, disregarding the weight or density of the air at different temperatures, the difference between 70 degrees and 140 degrees will represent the loss by radiation and conduction. If, with the same entering temperature, the loss is greater, the temperature of the room will be lower, and vice versa. There is thus lost $\frac{70}{140}$, or one-half, of all the heat by this means; or if, for ready comparison, each degree be represented as a unit, not of heat, but merely of relative measurement, 70 units will have been lost. If, in a given time, a given volume of air be delivered to the room, its cost in total heat expenditure must be measured by the number of degrees its temperature has been raised above zero; that is, upon the above basis of comparison, it will be equivalent to 140 units. In the given time all of this air must escape at the temperature of the room; hence, the loss by this means will also be 70 units.



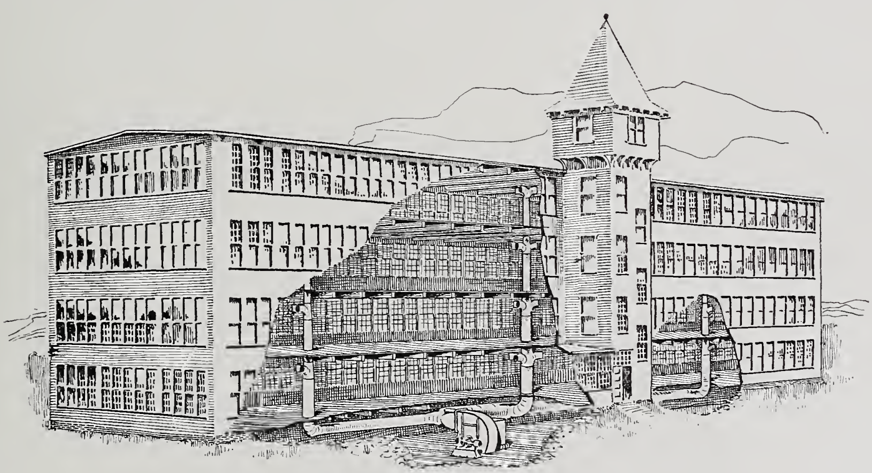
TYPICAL METHOD OF HEATING A SHOP BUILDING OF THE GALLERY TYPE

If the temperature of a given apartment is to be maintained at 80 degrees,

for instance,—the rest of the building being at 70 degrees,—there is to be considered as available for heating, only the increment between 80 degrees and 140 degrees or 60 units on the previously assumed basis. But the heat required for the warming process being proportional to the temperature difference between internal and external air, is $\frac{80}{70}$ of that previously necessary, while the amount available is only $\frac{60}{70}$. Hence, if no supplementary heating surface be employed, the air supply must be increased to $\frac{80}{70} \div \frac{60}{70} = 1.33$ times that required to maintain a temperature of 70 degrees.

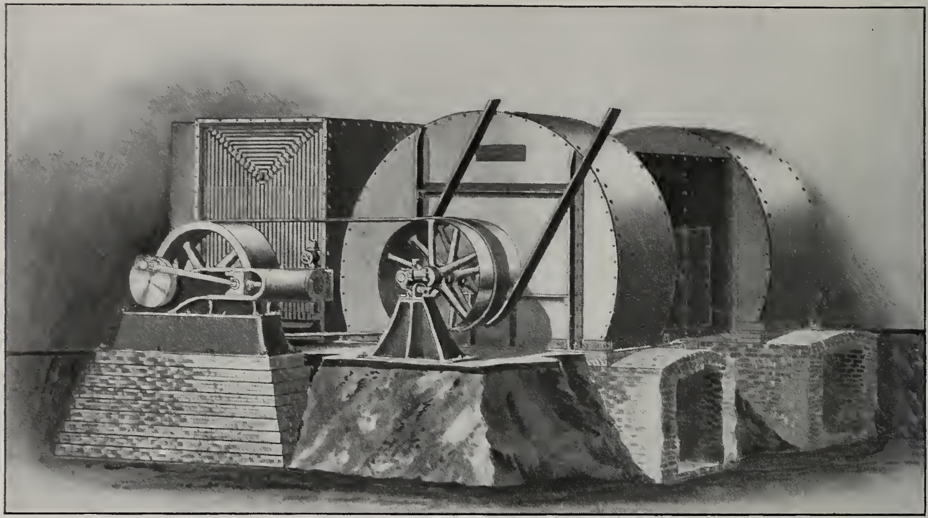
In the familiar gallery type of manufacturing building the problem of air distribution becomes somewhat more complicated than in simple one-story structures, because of the impossibility of carrying the pipes, or of successfully forcing the air, across the central space through which the crane travels. It, therefore, becomes necessary to provide for distribution upon both sides. The best method consists in placing two independent apparatuses, one in either gallery, midway of its length, and arranging them to discharge into pipes overhead and underneath, extending lengthwise of the building, and from which the air is delivered through outlets toward the cold outer walls. From the ends of the main pipes air may be forced for considerable distances nearly lengthwise of the building, but slightly deflected toward the side walls, thereby reducing the extent of distributing pipe necessary. This is an ideal arrangement for the return and reheating of the air, as it is centrally drawn from all directions.

In buildings of more than one story the arrangement adopted must depend largely upon the character of the construction of the building. Under all conditions it is usually desirable to place the apparatus in the basement as near the centre of the structure as possible, and to secure uniform distribution from it. In a wooden building with large window area, galvanised iron distributing pipes must be employed, and can best be introduced as individual risers, 40 or 50 feet apart, along the centre of the building. They may be supplied from a central pipe in the basement, and should be provided with four outlets each upon each floor, so as to secure equal distribution of the air. Where the building is narrow, proportionately low velocities are required, and draughts must be avoided.



HEATING A CONVENTIONAL FACTORY BUILDING

The relatively large number of occupants in such a building sometimes demands, for good ventilation, a supply of air slightly in excess of that usually



A MILL HEATING APPARATUS, EITHER BELT OR ENGINE DRIVEN

provided as an incident of the heating. An air change once in 16 minutes,—the average previously mentioned as common to the ordinary factory building,—is sufficient to supply at least 30 cubic feet per minute to each occupant when the per capita space is not less than 500 cubic feet. This, in a building with 12 feet clear height of stories, is equivalent to a floor space measuring about 5 feet by 8 feet per occupant.

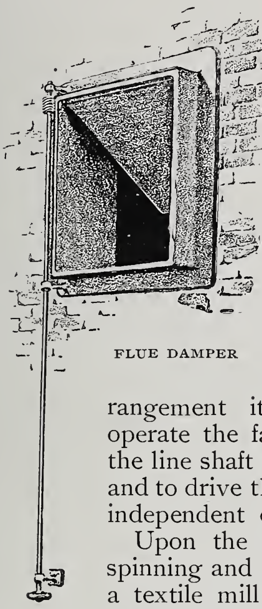
The per capita space per pupil in a school-room of approved dimensions is about 250 cubic feet. Individual air supply at the rate of 30 cubic feet per minute is, under these conditions, equivalent to a complete change of air once in a little over 8 minutes, and the maintenance of a degree of vitiation measured by the presence of about 7⅓ parts of carbonic acid in 10,000 parts of air. It is, therefore, evident that unless the per capita space in a factory is less than twice that in a school-room,—where close seating is a practical necessity,—the ventilation will be superior in the former structure when both are heated by the fan system.

In a building of brick or stone already constructed, a similar arrangement may be employed, or the vertical flues may be placed immediately against the walls upon one side of the building, and the air from a number of outlets forced along the walls as well as across the building.

Probably the best example of the symmetrical application of the fan system to factory heating is to be found in the modern American textile mill. Its uniform arrangement throughout is particularly conducive to simple application of the system, and to thorough distribution of the air. As a substitute for metal piping, vertical flues may be built in the form of external pilasters, 40 to 50 feet apart, along one side of the building. This is illustrated in the cut on page 139. One of the pilaster flues is shown on the opposite page. In the basement may be placed the apparatus discharging into a brick duct, usually quadrant in form, which extends along one side of the basement and communicates with the bases of the various flues. Each flue is reduced in area as openings are made to the various floors at about 8 or 10 feet above the floor level, and each opening is provided with a special form of damper which serves the double purpose of deflecting the air toward the room when open, and of preventing admission when closed. The large amount of moving machinery, pulleys, belts and

shafting in such a building, serves to thoroughly break up all air currents, and effectually distribute the air. Remarkable equality of temperature is thereby maintained.

In the most perfect type of hot-blast apparatus for a textile mill of considerable size, it is customary to install two fans with a common shaft, which is extended beyond the side of one of the fans and provided with three pulleys, of which the middle one only is fixed to the shaft, those upon either side being fitted to run free on sleeves extending from the adjacent journalboxes. With this arrangement it is possible to operate the fans by belt from the line shaft during the day, and to drive them by a special independent engine at night.

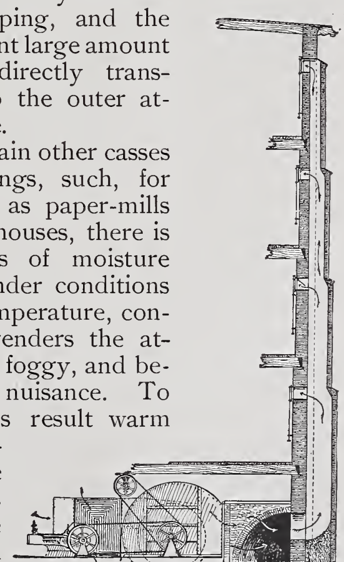


FLUE DAMPER

Upon the humidity of the spinning and carding rooms of a textile mill depends largely the effect of the frictional electricity which is generated by the motion of running stock and machinery. A humid atmosphere readily absorbs this electricity, and avoids the otherwise disastrous effects upon the stock. More or less complicated devices have been introduced for the purpose of moistening the atmosphere in such rooms, but the absolute simplicity of a fine spray, introduced in the duct from the heating apparatus where the fan system is used, is so great as to give this system manifest superiority.

It is difficult to make proper comparison of first cost and running expense between direct heating methods and the fan system of heating, ventilating, and moistening. The accompanying table, however, furnishes an unusually good basis of illustration. Two American textile mills, nearly identical in construction, and belonging to the same corporation, were equipped, the one with direct radiation and the other with the fan system. The former, known as Mill No. 1, was provided with a complete independent moistening system. In Mill No. 2 the fan system was installed for the combined purposes of heating, ventilating, and moistening. The cubic contents of the latter building were slightly the greater, as was also the exposure. Nevertheless, the first cost of the system per 1000 cubic feet of space was only 73 per cent. of that in the No. 1 mill, while the temperature maintained was much higher with a fuel expenditure of only 64 per cent. of that required in Mill No. 1. Although the air supply was ordinarily taken from the building, the natural leakage was so great as to provide ample ventilation. The relatively great cost of heating by direct radiation was in this case undoubtedly due to the excessive heating of the walls by the adjacent piping, and the consequent large amount of heat directly transmitted to the outer atmosphere.

In certain other casses of buildings, such, for instance, as paper-mills and dye-houses, there is an excess of moisture which, under conditions of low temperature, condenses, renders the atmosphere foggy, and becomes a nuisance. To avoid this result warm air in considerable quantities may be forced in by means of a fan, as the simple result-of introducing this system of heating. Because of its relatively high temperature and low humidity, this air greedily absorbs the moisture suspended in the atmosphere, and



A PILASTER FLUE

renders it invisible. In the case of a machine room in a paper-mill, for instance, large volumes of warm air discharged close to the ceiling will prevent the deposition of moisture and consequent dripping, which is so annoying and the cause of so much expense for repairs.

In a foundry equipped with the fan system, large volumes of air at moderate temperature may be forced in while the heat is in progress, thereby both clearing the atmosphere and rendering it comfortable for the men. In other classes of buildings where more or less objectionable odours, vapours, or gases result from the manufacturing processes, the admission of large volumes of air tends to very materially reduce the inconvenience and possible danger.

In the piano factory, the carriage works, the paint car shop and elsewhere where rapid drying of varnished or painted surfaces is necessary, the fan system serves to materially facilitate the process. All objection to dust in the atmosphere may be avoided by properly filtering the air before passing it through the fan. Numerous adaptations occur in every-day practice where the convenience of the massed heating surface, or the effects of thorough ventilation have definite commercial value. Like all applications of this character, the conditions must control the method, but augmented experience proves the best medium through which to secure more satisfactory results.

Comparative Cost and Running Expenses for Heating, Ventilating and Moistening Systems, Mills, Nos. 1 and 2, for 6 Winter Months

Cost of Introduction	No. 1*	No. 2†
First cost heating and moistening system	$4,600.00	-------
First cost heating, ventilating and moistening system	-------	$4,000.00
Cubic contents, cubic feet	1,103,852	1,316,520
Average temperature	70°	78°
Cost of system per 1000 cubic feet	$4.17	$3.04
Ratio	100	73
	137	100
Running Expenses		
Coal burned for heating	317,100 lbs	-------
Coal burned for moistening	58,500 "	-------
Coal burned for both heating and moistening	375,600 "	-------
Coal burned for heating, ventilating and moistening	-------	286,900 lbs.
Coal burned per 1000 cubic ft.	340.26 lbs.	217.92 "
Ratio	100	64
	156	190

* Overhead direct radiation and moistening system.

† Fan system of heating, ventilating and moistening.

ELECTRIC PROGRESS

By Edwin J. Houston, Ph.D.

THE advanced position which all the physical sciences and the useful arts connected with them occupy to-day, has necessarily been a matter of gradual growth. Though the great book of Nature is ever open to all who earnestly desire to discover the laws which govern her phenomena, yet success in correctly unravelling the apparently tangled chains of successive physical phenomena requires unwearied application and special ability. The separate links in the great chains of natural phenomena constitute the successive causes and effects of such phenomena.

To properly comprehend such a chain, none of its separate links can be disregarded. Each must be carefully studied both as an effect and as a cause; as an effect, to ascertain its antecedent cause; as a cause, to discover the effect it subsequently produces. The missing of any of these links renders the comprehension of the chain, as a whole, uncertain and unsatisfactory. Separate, detached portions, unless in fairly good lengths, can be but vaguely comprehended, so that to-day the world's vaunted knowledge of physical phenomena,—a knowledge which is, relatively speaking, undoubtedly great,—is, nevertheless, sadly incomplete. Too much of such knowledge still consists of short, incomplete, and apparently hopelessly disconnected lengths. Every now and then a missing link is discovered which binds detached and heretofore apparently incongruous positions together. The new light thus made available leads to the discovery of other missing links, and the investigator is thus enabled to advance still further along the lengthened chain into the great unknown and thus to extend, somewhat further, the horizon which now limits the world's knowledge in his particular branch of physical science.

There is a necessary and intimate relation between the physical sciences and their allied useful arts. So intimate, indeed, is this relation that, strictly speaking, no sharp lines of demarcation can properly be drawn between them. It is true, as Whewell holds, that the sciences teach one to know, and the arts teach one to do, but this distinction refers more to the end than to the thing itself; science teaches one to know what is true, for the sake of truth alone, while art teaches him to be able to put such knowledge to actual use. It is untrue, therefore, that the useful, practical arts cannot be classed among the sciences.

If the knowledge of many, so methodically arranged and digested as to be readily attainable by one, is properly to be regarded as a science, then a similarly arranged and digested knowledge of how to apply it to the useful arts may be properly regarded a technical science. Karslake, therefore, falls into a strange error when, contrasting the respective fields of physical science and the useful arts, he says that " science is more concerned with the higher truths, art with the lower," since both are concerned with precisely the same truths; and he is even farther from the truth when he asserts that " science never is engaged, as art is, in productive application," since the wonderful progress the world has made in the useful arts has been because science is to-day very much

engaged in productive application. This attempt to divorce the physical sciences from their allied useful arts is in reality a relic of that ancient time when those arts were known as the servile arts, because carried on solely by slaves. Happily for the world's progress, this distinction no longer exists. There are no higher and lower truths to be ascribed respectively to science and the useful arts, unless, indeed, the higher truth be assigned to the latter. The highest attainable knowledge of the laws of nature is by no means reached in the physical laboratory, where minute quantities of material are subjected to the operation of comparatively feeble forces for exceedingly limited periods of time. It is rather to be gained in the useful arts, where extended commercial repetitions of these laboratory experiments are continuously carried on, day after day, on thousands of tons of material and with powerful forces.

But while the physical sciences and their allied useful arts have reached the advanced positions which they occupy to-day by a gradual growth, that growth has by no means been equally distributed throughout the time these sciences and arts have existed. In many, the periods of marked advance have been separated by long intervals during which progress has apparently been arrested. This is especially true of the electric sciences and their allied useful arts. Tracing the history of the world's progress in this direction, it will be seen that such progress has been exceedingly irregular. Marked intervals exist between successive advances, and, while the birth of the useful arts was generally coeval with each advance in different branches of electric science, yet, perhaps with a single exception, the most marked and extended advance in the great commercial application of these arts has occurred during the last decade and a half, or since the year 1884.

The earliest recorded fact in electricity dates back to about 600 B. C., when the Greek, Thâles, discovered that a bit of amber, when rubbed against the clothing, acquired the curious property of attracting light objects. Although the mighty force of electricity had, of course, existed in the world just as it does to-day, in the lightning flash, the aurora borealis and other natural phenomena, yet it had absolutely failed to attract the attention of intelligent men prior to this time. Nor, indeed, did the discovery of Thâles apparently attract any special attention. With the exception of a brief mention by Theophrastus, about 321 B. C., of similar properties acquired by lyncurium (possibly either tourmaline or hyacinth) when subjected to friction, it was actually more than two thousand years before Gilbert and others, about 1600 A. D., had added several additional substances to the above-named bodies.

It is true that in the field of magnetism the Chinese are said to have been acquainted with the directive power of the loadstone, and to have employed it for practical purposes as early as 2600 B. C., and that since about 1000 B. C. the existence of a magnetic force was recognised to some extent by the ancients, and was employed generally in navigation since 1200 A. D., Columbus, in 1492, having himself observed the variations in the needle. Not much advance, however, had been made in magnetism until Hartmann, in 1544, and Norman, in 1576, had independently discovered the dip of the magnetic needle. But even then the missing link that united certain chains of magnetic and electric phenomena had not yet been discovered, so that this advance in magnetic science failed to exert any influence on the world's knowledge of electricity.

Even after the time of Gilbert, in 1600 A. D., electric progress was comparatively slow. It is true that Guericke and Hawksbee, in 1675 and 1700, respectively, had produced fairly effective frictional electric machines; that Newton, in 1675, had observed that a glass plate, excited on one side, was thereby electrified on the opposite side; that Gray and Wheler, in 1729, had produced motion in light bodies at a distance of about one-eighth of a mile by means of the so-called frictional elec-

tricity, a point of interest in connection with the telegraph; that DuFay conducted, between 1733 and 1737, experiments which resulted in his famous double-fluid hypothesis of electricity; yet no great discovery in electricity was made until 1745, when Von Kleist discovered the Leyden jar,—the earliest type of the electric condenser. This was a memorable discovery, and, like all discoveries of this character, has more than a single claimant, as, for example, in this case, Muschenbroek and Cuneus.

The discovery of the Leyden jar attracted considerable attention and gave a new impetus to the study of electricity, which, during the next half century, resulted in a considerable advance in the science. Briefly reviewing some of the most important discoveries of this half a century, we note that in 1746 Watson had proposed a single-fluid electrical hypothesis, similar to that communicated to the Royal Society by Franklin, in 1747. Nollet, in 1746, had discovered the increase in the flow of liquids through capillary tubes while under the influence of electrification. Watson and Franklin had demonstrated the possibility of transmitting electric discharges through land and water in 1747 and 1748, respectively,—facts of considerable interest in connection with the telegraph.

Franklin, in 1752, outrivalling Prometheus, had indeed stolen the sacred fire from heaven, thus robbing Jove of his thunderbolts, and shortly afterwards elevated this knowledge to a still higher plane by employing it in the construction of a lightning-rod for the protection of buildings from lightning flashes. Æpinus, in 1759, and Canton, in 1760, had discovered what is now known as pyro-electricity, or the electrification produced by the unequal heating of certain crystalline bodies. Volta, in 1776, had produced the electrophorus. Becaria, in 1777, had observed that an electric discharge, sent through a magnetic needle, curiously affected its polarity, thus coming dangerously near robbing Oersted of his famous discovery, in 1820, of the relation existing between electricity and magnetism.

Coulomb, in 1785, had employed the torsion balance and proof plane for the valuation of electric forces. Haüy, in 1785, had extended the earlier discoveries of Æpinus and Canton in pyroelectricity, and, in 1787, had shown that electrification could be produced in certain crystalline bodies not only by differences of temperature, but also by differences of pressure. Cavallo and others in 1788 produced their then famous doublers of electricity. Fourcroy, Vanquelin and Seguin in 1770 had begun the initial experiments showing the power possessed by electric discharges of effecting chemical decomposition, thus preparing the way for the later discovery of electrolysis. But probably no discovery made during this term was so important in the discovery growing from it, as that made by Galvani in 1786, in connection with the convulsive movements of the hind legs of a recently killed frog, when subjected to an influence, which was afterwards proved by Volta to be that of an electric discharge.

Such, briefly, was the extent of the world's knowledge of electricity near the beginning of the nineteenth century. Though fairly extended, it was, in the light of our knowledge to-day, quite limited, and in many respects vague and unsatisfactory. Those desiring to know more accurately the extent of such knowledge at that time, as well as the belief then existing as to its completeness, will find much of interest in a book entitled "A Treatise on Electricity," published in 1795, by one Tiberius Cavallo. The author discusses in the preface to his book the effect which the discovery of the Leyden jar had in giving a new impetus to the study of electricity, and refers to the wonderful advance made at the time, 1795. Concerning the discovery of the Leyden jar, in 1745, he says:—

"Since the time of the discovery, the prodigious number of electricians, experiments, and new facts that have been daily produced, from every corner of Europe and other parts of the world, is almost incredible. Discoveries crowded upon discoveries; improvements upon

improvements; and the science ever since that time went on with so rapid a course, and is now spreading so amazingly fast, that it seems as if the subject would soon be exhausted, and electricians arrive at the end of their researches; but the *ne plus ultra* is, in all probability, as yet at a great distance, and the young electrician has a vast field before him, highly deserving his attention, and promising further discoveries, perhaps equally or more important than those already made."

It was in 1796, or one year after the close of the half century we have just considered, that another era-producing discovery was made. This derived its importance from the ready means it put into the hands of the electrician of producing electricity in far greater quantities than had heretofore been possible. We refer to Volta's invention of the voltaic pile which grew out of the prior discovery of Galvani as to the convulsive movements of the frog's legs. It was publicly announced to the Royal Society in 1800.

The nineteenth century thus opened auspiciously for electric science. By means of the current produced by a voltaic battery, on the 2d of May, 1800, Nicholson and Carlisle decomposed water, and in the same year Henry, of Manchester, effected the electrolytic decomposition of nitric and sulphuric acids, this effecting readily what Fourcroy, Vaquelin, and Seguin had, in 1790, accomplished by a series of discharges continued without intermission for upwards of ten days.

Passing by a number of interesting but comparatively unimportant discoveries, we come to the immortal discovery by Davy, in 1807, of the compound nature of the alkalies. By means of the current produced by a voltaic battery of two hundred and seventy-four cells, this physicist succeeded in decomposing potash, thus producing metallic potassium. Shortly afterwards Davy greatly extended this discovery by demonstrating that all the earths and alkalies, until then regarded as elementary, were in reality compound substances.

It is difficult for us, so long after this great discovery, to properly estimate the enthusiasm it produced in Davy's contemporaries, and, indeed, in the entire world. Some idea of this might be had from the effect that would be produced in our time should it be demonstrated that any of the metals themselves, for example, gold, silver, platinum, and copper, were compound substances, and might, therefore, be produced by the direct union of their components.

Telegraphic science received some aid during this period. Soemmering invented his electrolytic telegraph in 1809, and Coxe a similar telegraph in 1810; while Sharpe, in 1813, and Ronalds, in 1816, each produced new telegraphic apparatus.

The powerful currents produced by the voltaic batteries of this time naturally resulted in the discovery of the great heating and illuminating power of the voltaic arc, both when formed between metallic and carbon electrodes. The discovery of the great illuminating power of the carbon voltaic arc, generally attributed to Davy, was, in reality, made by others. Davy, however, was, perhaps, the first to publicly demonstrate its peculiar fitness for artificial illumination and to exhibit a powerful carbon arc light. This he did in 1809, at the Royal Institution in London, employing for this purpose a voltaic pile formed of two thousand couples.

Passing over a number of minor discoveries, we come to the crowning work of the first quarter of the nineteenth century,—the demonstration by Oersted, in 1820, of the long-suspected relation between electricity and magnetism. While Davy's discovery of 1807 was the great discovery of this period from the standpoint of chemical science, and while the discovery first made public by his demonstration of 1809 was of immense importance as laying the foundation of the art of electric lighting, yet, so far as advance in electric science is concerned, neither of these discoveries led to such important results as did that of Oersted. Indeed, without this generalisation of Oersted, which directly led to the subsequent discoveries of Faraday, Sturgeon, Henry, and others, the

dynamo-electric machine would have been impossible, and electric lighting would have failed of practical realisation, owing to the commercial impossibilities of producing, by the use of voltaic batteries, the enormous current required by the art.

Like most great discoveries, that of Oersted was of marked apparent simplicity. Many other investigators before his time had sought in vain to evoke the phenomena of magnetism from the voltaic battery, but had failed because they had operated with an open instead of with a closed circuit. Oersted simply closed the battery circuit by a conductor, and demonstrated that, as long as this conductor was active, *i. e.*, as long as it conveyed an electric current, it possessed all the properties of a magnet.

In discussing the importance of Oersted's early work, we must not be unmindful of the valuable discoveries of Ampère, made about the same time, which threw much additional light on the mutual relations of electricity and magnetism. Ampère's work in this direction was especially valuable; he showed that the magnetic needle employed to demonstrate the attractions and repulsions of an active wire, could, itself, be replaced by another wire, or, in other words, that not only does every active conductor affect a free needle as another magnet would, but that also all active conductors affect each other like magnets. Moreover, he showed that an active helical conductor perfectly imitated a permanent magnet, thus preparing the way for the production of the electro-magnet by Sturgeon and Henry at a somewhat later date.

The great discovery of the second quarter of the nineteenth century was that of Faraday in 1831,—magneto-electric induction, or the production of electricity from magnetism. It was the reverse of Oersted's discovery of the production of magnetism from electricity. Faraday found that when a coiled wire was suddenly separated from a permanent magnet, an electric spark was produced. He also demonstrated that when a permanent bar magnet was suddenly thrust into, or withdrawn from, a coil or helix, an electric current was developed in the coil, flowing in one direction on the insertion of the magnet, and in the opposite direction on its withdrawal. He also demonstrated, in the same year, that a current was produced in a copper plate when rotated between a pair of magnet poles, thus both producing the first dynamo-electric machine, and pointing out the way in which currents could be produced by the rotation of coils of wire in front of magnet poles.

Faraday's discoveries soon led to the production of fairly powerful magneto-electric machines, which were the forerunners of the modern dynamo. Such were the early machines of DalNegro and Pixie, in 1832, of Saxton, in 1833, and the subsequent machines of Clarke, Ritchie, Jacobi, Sturgeon, Wheatstone, Cooke, Nollet, Von Maldern, and many others. In 1854 Hjorth had discovered the reaction principle whereby the field coils of a dynamo machine were strengthened by the current generated in the armature, each strengthening the other until the machine thus "built up" or became capable of developing its full working current. This same principle was independently discovered by Werner Siemens, and by Wheatstone in 1867. Numerous inventions followed, the dynamo-electric machine of the third quarter of the nineteenth century reaching its culmination in the famous machine of Gramme, about 1870.

Another important invention belonging to the second quarter of the nineteenth century was that of the electric motor. Henry, in 1831, and DalNegro, in 1832, had suggested and described methods for employing electro-magnetism as a motive force. Ritchie and Sturgeon, in 1833, Jacobi, in 1834, and Page, in 1850, had produced fairly operative electric motors. Nor had this period neglected the development of the electrolytic power of the current. Jacobi, in 1838, and, somewhat later, Elkington and Wright, had invented galvanoplasty, or electrotyping, the cold casting of metals by electrolytic deposition.

The second quarter of the nineteenth

century also witnessed the introduction of practical systems of electric telegraphy. Daniell, having produced his constant voltaic cell in 1836, the way was prepared for the invention, in 1837, by Morse in America, by Steinheil in Germany, and by Wheatstone and Cooke in England, of electro-magnetic telegraphs that are substantially like those employed to-day. During the balance of this period great attention was given to telegraphy, and in 1858 Field accomplished the laying of the first Atlantic cable.

Up to this time there had been no extensive commercial applications of electricity. Frequent efforts had been made to introduce the electric light for every-day use. Staite, Petrie, Foucault, and many others had produced electric lamps; but, as already mentioned, the voltaic battery, the only electric source available then, was too expensive, and telegraphy was practically alone in the commercial field. The reduction of electric science to practice, as witnessed in the operation of the Atlantic cable, involving, as it did, the investment of considerable capital, necessitated a more accurate knowledge of electrical laws, and electrical engineering may be considered as dating its origin from this time.

The most important step during the third quarter of the nineteenth century was unquestionably this laying of the Atlantic cable in 1858. Most of the discoveries made about this time were connected either directly or indirectly with electro-magnetic telegraphy. The suitability of gutta-percha for the insulation of submarine cables was put to test; the phenomena of electric charge in telegraphic wires were carefully studied; the existence of earth currents was demonstrated, and various improvements were made in telegraphic apparatus.

In addition to things telegraphic, we may note that during this period Ruhmkorff, in 1851, produced his famous induction coil; Matteucci, in 1856, had made important electro-physiological researches; the British Association, in 1864, had published their reports on standards of electric resistance; dynamo-electric machinery, as we have already seen, had been greatly improved during this time, Gramme having produced his dynamo about 1870; and another, but still unsuccessful attempt, was made to commercially introduce electric lighting, both arc and incandescent, on an extended scale.

The last quarter of the nineteenth century, which brings us to our own time, has been a period of marvellous activity in electric science. The excellent dynamos of Gramme, Siemens and Halske, Hopkinson and others in Europe, and of Brush, Weston, Thomson and Houston, Edison, Westinghouse, Walker, Crocker and Wheeler, and others in America, have assured cheap electric current, and rendered its extended commercial application possible. Another attempt was made to introduce the electric light on an extended scale, and this time successfully. Improvements were made in generators, lamps, both arc and incandescent, and systems of distribution, which culminated in the extended use of this method of lighting that exists to-day. Moreover, other extended applications of the direct current were made, such as the present system of electric tramway propulsion.

Besides these applications of the direct current, the use of alternating currents has been greatly extended during this time and valuable discoveries and inventions have been made in this branch of electric science. Although alternating currents were known long before 1876, they had, until a comparatively recent date, failed to be extensively used. Among other things, improvements were needed in alternating-current transformers, and the production of practical polyphase motors, before the manifold advantages of alternating currents over direct currents for certain kinds of work could be rendered available. A host of illustrious investigators and inventors have rendered conspicuous service in this work. Through their investigations an almost new science, that of alternating electric currents, has been created within the already existing electric science, and new types of apparatus

have been introduced, with names still strange to the general public. By the aid of modern alternating-current apparatus, electric power transmission over considerable distances has become a commercial possibility and has come into extensive application.

The work done in incandescent lighting during this quarter century has been marked. Like arc lighting, this branch of the electric arts had its birth not long after the invention of the voltaic pile, and, like arc lighting, it, too, had its periods of unsuccessful effort. As early as 1845 King had invented a lamp in which a small pencil, or thin plate of carbon, placed in a glass chamber in a Torricellian vacuum, was rendered incandescent by the passage of an electric current. Roberts, in 1852, had also produced a lamp in which light resulted from an incandescing conductor in a high vacuum, and Konn and many others had laboured in the same direction. But none of these lamps ever came into extended use.

It was not until near the beginning of the last quarter of the nineteenth century that another series of improvements in incandescent electric lighting began, and this, continuing until the present time, has resulted in the enormous use of this form of artificial illumination that exists to-day. Among the many who have contributed to this later work are Lane and Fox, Swan, Maxim, Sawyer and Man, and Edison, conspicuously the last mentioned.

During this period an important application was made by Marconi and others, of electro magnetic waves in wireless or space telegraphy. Electromagnetic radiation had been known long before. As early as 1864 Maxwell announced his hypothesis as to the identity of electro-magnetic waves and ordinary light. Indeed, even in 1842 Henry had observed that needles in the cellar of his house were magnetised by a condenser discharge in an upper room. Hertz, in 1888, corroborated Maxwell's hypothesis, and by employing the principle of resonance showed that the velocity of propagation of electro-magnetic waves is practically the same as that of light. Herz's experiments were extended by Lodge and others in 1890, and afterwards, in 1893, Preece described experiments in wireless telegraphy, in which messages were successfully transmitted over the British Channel for a distance little more than one mile. Marconi and others have either greatly improved the old apparatus, or devised new systems, by means of which the working is more certain and the distance of actual communication markedly increased. Although Marconi's system of telegraphic communication does not appear likely to become, in the near future, a formidable rival to existing systems of telegraphy, yet it undoubtedly possesses great future possibilities.

Another possible form of electromagnetic waves that has recently come into extended commercial use is to be found in the so-called X-rays. This peculiar form of radiation has proved of great service to the surgeon and physician from the aid it affords in locating foreign metallic substances in the human body, as well as indicating abnormal conditions of its tissues and organs. It has been enabled to do this in connection with photography by reason of the peculiar behaviour of the radiation as regards many substances opaque to ordinary light. The Wehnelt interrupter, which has proved of great service in connection with X-ray induction apparatus, has also been a matter of recent discovery.

We have thus briefly traced, from its remote birth to the present day, the progress of electric science and its allied useful arts. We have shown that such progress has been by no means equally distributed throughout time, periods of marked advance being separated by intervals in which further progress has apparently been arrested. We have seen how further advance has been aided by certain great discoveries or applications, and that these have occurred at irregular intervals.

In closing this brief review, attention should be called to the fact that the last quarter of the nineteenth century, indeed, more correctly, the last decade and a half of this period, has been emi-

nently characterised by extended commercial applications of electricity. If the nineteenth century has correctly been called the age of electricity, its last decade and a half may properly be designated as the age of the commercial applications of electricity.

It is not the writer's purpose here to attempt to assign any reason for the wonderful increase in the commercial application of electricity that has taken place during this time. The great International Electric Exhibit, held in Philadelphia in 1884, under the auspices of the Franklin Institute of the State of Pennsylvania, was, probably, one of the principal causes. Other causes unquestionably concurred, but the fact exists that nearly all the great commercial applications of electricity were made after 1884.

A brief statement as to the extent of the commercial applications of many of the electric arts to-day may not be inopportune here. Take, for example, electric lighting, arc and incandescent, with both direct and alternating currents. Many important cities and towns have now adopted this method of lighting, and in nearly all there are separate stations provided for different localities. In addition to these central stations there is in each a number of isolated plants, which in the case of some of the tall office buildings in the United States, almost equal in their total output of current that of moderately large central stations. As an illustration of this, take the city of Boston, where there are to-day twenty-nine generating stations and one hundred and ninety-five isolated or private plants. The combined number of dynamos in these plants have a total capacity of current output sufficient to operate 424,443 incandescent lamps, 13,094 arc lamps, and 7070 electric motors. To drive these dynamos there are required 90,382 H. P. of boilers and 66,774 H. P. of engines.

Or, consider the wonderful growth of electric traction. In the United States alone the gross receipts of a single year, 1898, of two hundred and twenty-two electric street railways reached the vast sum of $128,000,000 (£25,600,000). Of these two hundred and twenty-two roads, twenty-six had annual gross receips of $1,000,000 (£200,000) or over; twenty showed annual gross receipts of between $500,000 and $1,000,000 (£100,000 and £200,000); fifty-eight, between $100,000 and $500,000 (£20,000 and £100,000); sixty-two, between $50,000 and $100,000 (£10,000 and £20,000); and the remainder, between $25,000 and $50,000 (£5000 and £10,000).

The commercial applications of the telegraph and the telephone, particularly the latter, have been especially extended since 1884. Telegraphic communication is now possible to practically all parts of the world. The growth in telephonic communication has also been enormous, especially in the United States. Some idea of this may be obtained from the statistics of a single city, say, those of New York. In 1895 there were a trifle more than 10,000 telephone stations installed. At the present time there are about 33,000 such stations, showing that the system has trebled in about five years. Taking New York City as it now exists, that is, including the old city, with the Boroughs of Manhattan and the Bronx, it is said to have in actual use more telephones than London and Paris jointly.

The storage battery, although originating in Planté's secondary battery of 1859, did not come into any extended use until after 1884. To-day its increased efficiency and length of life under the requirements of actual use, have enabled it to come into fairly considerable use in central stations in adding to the general output in times of maximum load. Moreover, its use for the propulsion of automobiles bids fair to assume enormous proportions in the near future.

The part played by electricity in the every-day lives in large cities is indeed manifold. By its means we light our streets, public buildings and houses, operate our street railways, transmit intelligence by telegraph or telephone, operate annunciators and systems of fire and burglar alarms, drive motors, render readily accessible cheap power from dis-

tant sources, and employ it in a great variety of other ways. Necessarily, all this requires an immense manufacture of electric apparatus. The examination of the annual report of a single large company in the United States shows that for the year ended January 31, 1899, the total sales, as billed to customers, amounted to more than $17,-260,000 (£3,452,000).

As to the requirements in any of the large American cities for electric wires and conductors to carry the electric current, it is worth noting that, in the city of Boston, there are, according to a recent report of underground systems alone, 726,997 feet of conduit, 3,469,-011 feet of duct, 5,427,483 feet of cable, and 167,751,793 feet of single conductors.

So much for the past decade and a half! As to the outlook for the future, none can doubt that still greater growth may be reasonably expected.

THE NEED OF TECHNICAL EDUCATION

A MEANS TO INDUSTRIAL SUPREMACY

By Sir Andrew Noble

TECHNICAL education is a phrase that has been so often misused, perhaps so often misunderstood, that many of those who, like myself, are engaged chiefly in trying to solve the practical problems of engineering, are in the habit of hearing it either with impatience, or of regarding it as a fad of lay theorists, or sometimes, I fear, as a cloak for educational shortcomings in other directions, and I am bound to confess, if their experience has been the same as mine, that there is some excuse for them.

A large number of persons, as stated recently in an address at the Central Technical College of the City and Guilds of London Institute, have assured me that their sons had no taste for books, but had shown a marvellous talent for engineering. This marvellous talent generally turns out to be an incapacity, possibly from defective education, for seriously applying the mind to any subject whatever. But technical education, properly considered, is of the highest importance. It is only its abuse that we have to guard against. One of the great abuses I take to be that technical education is often begun too early in life—that is, that it is substituted for a general education, and a boy attempts to put his knowledge to practical use before he has learnt how to learn. Another abuse is the divorcing of practice from theory, and the danger of elevating practical application above scientific knowledge.

Having been connected for many years past with the management of probably the largest engineering firm in England, the author has had exceptional opportunities for observing what educational antecedents are likely to produce the best results in the engineering field. I say "exceptional opportunities" advisedly, for we at present employ in our various works not far from 30,000 hands. Of these a large number are youths, often sons of workmen. I am continually asked what education I should recommend for a lad entering Elswick. I always say, "Send your son to as good a school as you can, keep him there as long as you can, do not curtail his time of schooling, do not stunt his early intellectual growth by narrowing it down to any special study as taught

at elementary schools." Science, mechanical drawing, and such like are no doubt very useful (as all knowledge is useful) in their way. These studies may prove an irresistible attraction to minds with a strong bent towards scientific subjects, but I would fancy most employers would rather that a lad came to them blankly ignorant of both so long as he had had a good education, had been taught, and had ability, to think and to concentrate his attention on any subject brought to his notice. The Duke of Wellington is said to have replied to a father who asked him what was the best education for his son preparatory to his joining the army, "The best education you can give him." It was a very pregnant utterance, terse and to the point, and it remains as true for any other profession as for the army.

In nine cases out of ten, I should say, any knowledge acquired by a boy before he is sixteen can have but a slight intrinsic value. Up to that age it is not what he learns that we have to look at, but how he learns; it is the habit of discipline, of mental application, of power in attacking a subject, that are so valuable, not generally any definite piece of knowledge he may have gained. According to my experience the most valuable knowledge that a man has at his disposal is that which he has taught himself. That a special technical education is not an absolute necessity is not difficult of proof. Lord Armstrong, for example, commenced life as a solicitor; James Watt was an instrument maker, and was prevented from opening a shop in Glasgow because he had not served a full apprenticeship; George Stephenson was an assistant fireman to his father at Killingworth Colliery; Faraday was brought up a bookbinder. I cite the cases of these great men simply to show how men without trained assistance have taught themselves, and what can be done by the dauntless energy, untiring industry, and patient search after truth, which were the great characteristics of all of them, and which enabled them to do such great things.

My own impression with regard to early education is that as a sharpener of the young intellect, and as a mental discipline, it would be difficult to improve upon the curriculum which is now in force at our public schools, and which, in the main, has been in force for so many centuries. I am not in accord with those who think that modern languages should supersede the classics as a means of education, and I should regret more than I do the attempts which have been made in this direction did I think that these attempts were likely to be successful. Men of science will remember that practically the whole of our scientific nomenclature is borrowed from the Greek and Latin languages, and personally I have found my own knowledge of the classics, which represents, no doubt, that of a very ordinary schoolboy, stand by me, and enable me to enjoy, as I would not otherwise have done, that noble literature which, as Lord Macaulay says, is the most splendid, and perhaps the most durable, of the many glories of England.

But whatever may be the fate of the classics as a means, I must take up my parable against a course of education I have seen in several primary schools where an attempt is made to teach boys, often little better than children, rudimentary chemistry, rudimentary geology, also physiology and electricity. Occasional popular lectures on these sciences may be of very great value to some boys in interesting them in these great subjects, and in leading them, at some later date, seriously to study them; but these sciences as taught in the schools I refer to can have little value in encouraging habits of thought, of application, and of mental discipline; and to knowledge so acquired the words of Pope are peculiarly applicable:—

> "A little knowledge is a dangerous thing,
> Drink deep or taste not the Pierian spring,
> There shallow draughts intoxicate the brain,
> And drinking deeply sobers it again."

I am aware that many people say that the years a boy wastes on Greek and Latin might be better employed in learning German and French. It may be so, but it is not difficult to teach these most important languages colloquially at a very early age; and with regard to

technical subjects, speaking from my own observation, I may say that I do not think I have known any man at 28 or 30 who was the better for having abandoned his general education for technical subjects at too early an age. Those men who with fair abilities have received a really good education, have been taught to use their minds, and who, by contact with other students, have acquired habits of application, amply make up for their late start by the power of mind and grip that they bring to their work. They are fresh and keen when others who have been hammering away at semi-technical work from early boyhood have become stale and are less vigorous; and that reflection moves me to deprecate strongly any attempt to teach seriously practical or electrical engineering in preparatory or elementary schools. As an excellent recreation, such studies are no doubt to be encouraged, but to make them a systematic part of education, to the exclusion of studies which have a more direct effect in developing the understanding, seems to me to be entirely wrong. I would go further, and say that even in public schools, and their equivalents for older boys, what are termed engineering shops are generally a failure so far as any efficient knowledge to be gained in them is concerned. Except as a reasonable diversion for recreation hours, such "shops" have, I fear, but little value, and in nine cases out of ten the hours spent in them are subtracted from the time due to more valuable studies.

In my judgment, the age at which a boy should seriously begin any special studies, with a view to fit him technically for the profession he may have decided to follow, should not be earlier than 17 or 18. And in any discussion as to the age at which a boy should leave school, the great incidental advantages that he gains from a reasonable prolongation of his school days must never be lost sight of. A stricter discipline, a wiser supervision, a more authoritative yet sympathetic advice as to conduct, are more possible at school than can ever be the case in after-life, and a more constant and generous association with his equals rubs off angularities and leads to amenity of disposition. It is seldom, indeed, that one cannot trace the difference between a lad who has had a full public school training and another who has been less fortunate. Speaking as an employer of labour, I should say that we find a pleasant speech and manner, tact in dealing with others, and some power of organisation of the utmost value, and it is precisely those qualities which a boy acquires or ought to acquire in his later years at a public school. Without such qualities even the highest scientific attainments will never make a captain of industry, and in selecting candidates for appointments the man of business distinctly prefers a youth who has had the benefit of some years at a good school. So much for the necessity of grounding technical studies on the basis of a sound general education.

The next point I should like to urge is, that any practical technical instruction and any practical knowledge acquired in the workshop should be based upon sound theoretical knowledge. I am driven to enforce this question because (speaking again from my own observations), I find that often far too much weight is given to practical skill and what is called the "rule of thumb," and far too little to sound theoretic knowledge. In the middle of this century English machinery was immeasurably superior to any other. To Great Britain remaining content with this state of things, and to seriously neglecting technical instruction, I attribute the very much greater comparative progress that Germany, the United States, and Switzerland have made in the last fifty years.

Turning to other departments of industry, no Englishman can observe without regret how certain branches have almost altogether abandoned Great Britain, and have been, in a great measure, left to those who have paid more attention to technical instruction. Nearly every requirement of a drawing office can be better and more economically obtained from Germany. From what source do all our pure chemicals come, our filter papers, and most of our

glass apparatus? I admit that the workmanship of many articles made in Great Britain cannot be surpassed, but if we require any original or special piece of apparatus we are frequently compelled to go to Germany or France for their manufacture. I do not desire to press my point too far, and admit that a portion of this transference of work, which I so much regret, may be due to cheaper labour. But the British mechanic is second to none, and if that false trade unionism which endeavours to prevent the most intelligent and skilled from reaping the full benefit of their abilities be abandoned, I do not despair of seeing Great Britain regain much that it has lost.

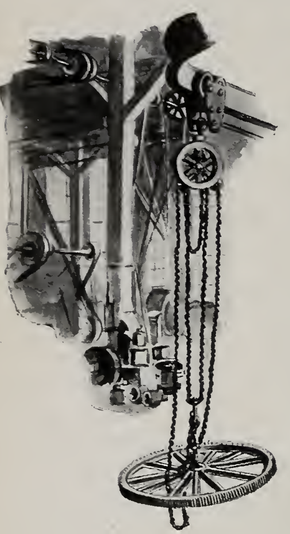
But it is to theoretic and technical knowledge that we must chiefly look. Consider, as an illustration, electricity in the service of man! Think of its innumerable applications, and of the number of hands dependent upon its industries! But for one man capable of designing or improving these powerful machines or delicate instruments there are a thousand ready and able to carry out their designs. But it is the former who are the salt of the earth, and those who have the management of large concerns know well how to value them. While it is an undoubted fact that no theoretic or technical instruction can supersede the necessity of obtaining practical experience in the workshop and factory, yet, on the other hand, I believe that no genuine success in the higher walks of industry is probable without thorough theoretic or technical knowledge. In my experience, I do not think I have ever known a man rise to the top of the tree without it. I may, perhaps, be forgiven if I refer to one great engineering genius, Lord Armstrong, with whom it has been my privilege to be so long and so intimately connected. In whatever investigation he was engaged, he added to sound theoretic knowledge an intensity of application and an apparently intuitive perception of the results to be expected that I have rarely seen equalled. Of him it may be truly said that, "whatever his hand found to do, he did it with his might." Sir William Harcourt, speaking on a recent occasion, attributed the immense commercial advance which has of late, been made by Germany to the better teaching of languages, and to the German merchant being able to speak to the English buyer in a tongue which he can understand. I very much doubt if that has much to do with the matter, and I am sure that houses where business is done on a large scale very much prefer that all letters should be in the languages of the respective writers, and not in the doubtful English that is not infrequently thrust upon us. There is no doubt that Germany is competing with us, as she has a right to do, successfully, and, so far as I am aware, with respect to her manufactures, perfectly honestly. I say "honestly," because I do not believe in any attempt to enhance the value of one's own wares by depreciating those of other people; and I entirely differ from those who would attribute the success of German competitors to their putting on the market inferior goods specially made to imitate those of a superior class. It was some idea of this kind, no doubt, that led to the most ill-advised regulation that foreign-made goods should be stamped so as to show their origin. It doubtless does this, but its effect is, I believe, in the direction of an advertisement for foreign goods, and there is some danger that if our own manufacturers relax their efforts, the "Made in Germany," which was, I think, meant to be a reproach, should become, on the contrary, a hall-mark of excellence, as when the *Kaiser Wilhelm der Grosse*, one of the finest steamships afloat, steamed into Southampton water with a facetious placard, "Made in Germany," hanging on her side. In many articles, and especially with the apparatus of scientific research to which I have referred, this is already the case.

Manufacturing progress has in Germany gone hand-in-hand with material progress, and any one who has travelled much must be astounded with the extraordinary improvement which has been going on in recent years, not only

in German railways, shipbuilding, and steelworking, but also in the buildings, order, and general amenities of life of the great German cities, such as Berlin, Frankfurt, and Cologne. In the competition of manufacture we are pressed very hard from steel to watches, from marine engines to scientific instruments. In nothing, indeed, have German manufacturers made more progress than in the making of all exact instruments. In these departments Germany certainly excels us, so far as original and inventive improvement is concerned. All this improvement, however, I feel inclined to attribute, not, with Sir William Harcourt, to any linguistic superiority, but to the far greater opportunities of technical study which are afforded in Germany. If we are to hold our own, we older men must try to multiply these opportunities of study in our own country, and the younger men must do their part, by seeking to avail themselves to the uttermost of any such opportunities provided.

DIRECT ELECTRIC DRIVING IN MACHINE SHOPS

By R. T. E. Lozier



THE many attractive advantages offered by electricity as a means of power distribution in industrial establishments may be presented under three headings:—

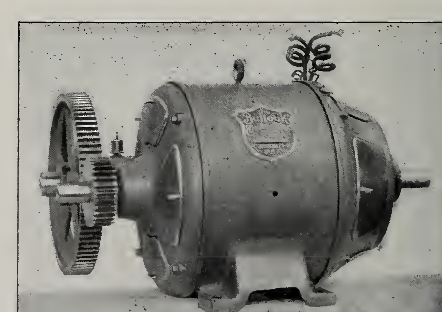
First. The rate of speed at which the tools or machines may be operated. This subdivision involves not only the range of speed, but the number of changes which can be effected throughout that range, and the ease with which these changes can be made.

Second. The amount of power necessary to produce a given amount of work. This involves primarily and essentially the efficiency with which the power can be distributed from the main source of supply to the points of consumption.

Third. What effect the form of power distribution will have upon the general arrangement and the morale of the establishment. In this will be involved the distribution of the tools or machines upon a given floor plan, and the light, ventilation, cleanliness and general appearance of the establishment.

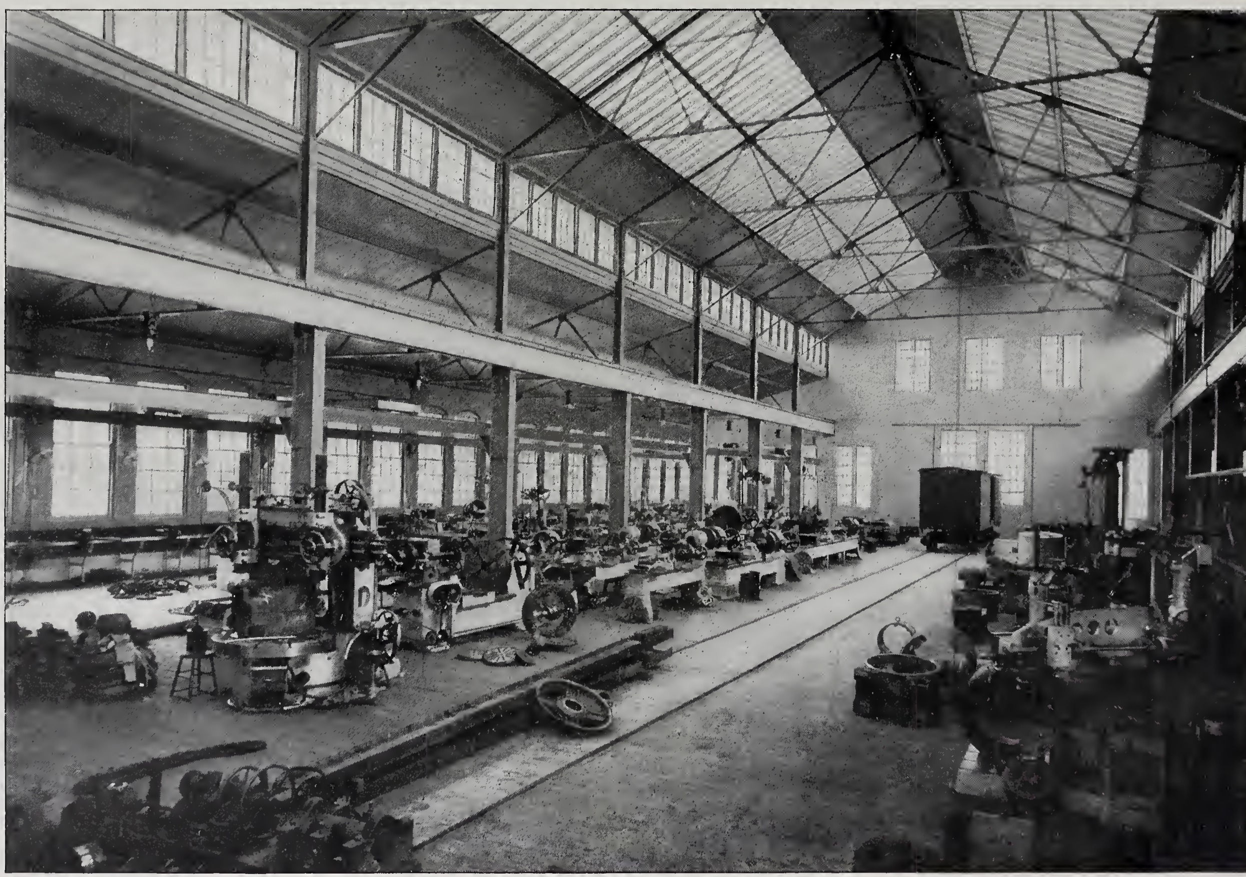
Before taking up these propositions in detail, it might be well to say that there appear to be but two forms of power distribution to be considered,—one in which the power is applied to the driving pulleys of the machines by belts which take the power from the source of supply by a series of other belts and shafting; and the other by delivering the power at the source o supply in the form of electricity and then transmitting it by wires to the points of consumption, either to motors directly connected to the tools, or to motors which are either belted to the tools or else belted to the subdivisions of shafting, which, in turn, drive the tools by belts.

As to the matter of speed of operation, it is worth inquiring whether it is not possible for the manufacturer who is using the long established method of belt drive to make his product at a higher rate with the same labour and equipment if he is able to supply his workmen with a greater range of speed for their tools or machines, and with a greater number of accelerations within that range than they have been familiar with in the past? Most of the tools and machines of the present day are limited in their speed by the driving gear with which they have been supplied when first purchased. The speed of these driving gears is the product of



A MODERN GEARED MOTOR FOR SHOP USE

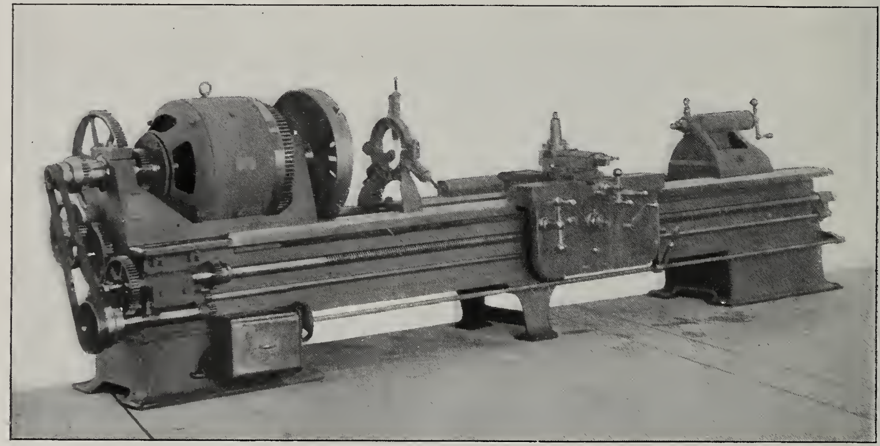
a law of averages and does not necessarily permit of the maximum results being obtained. The writer remembers well a case of a calico printing machine which was provided with three changes



A SHOP VIEW AT THE WORKS OF THE BULLOCK ELECTRIC MFG. CO., CINCINNATI, O., U. S. A. THE TOOLS ARE ALL DRIVEN BY INDEPENDENT ELECTRIC MOTORS AND THE USUAL LINE SHAFTING AND BELTING ARE CONSPICUOUSLY ABSENT

of speed obtained by a set of driving gears susceptible of three combinations. This gearing was displaced by an individual electric motor provided with a full speed range, and the general output of the printing press was increased by a very large percentage, reaching 80 per cent. with certain classes of work. Not only was the old speed range very much more limited than that found possible with the individual motor, but the gradations available with the motor were greater in number and very much more easily attained.

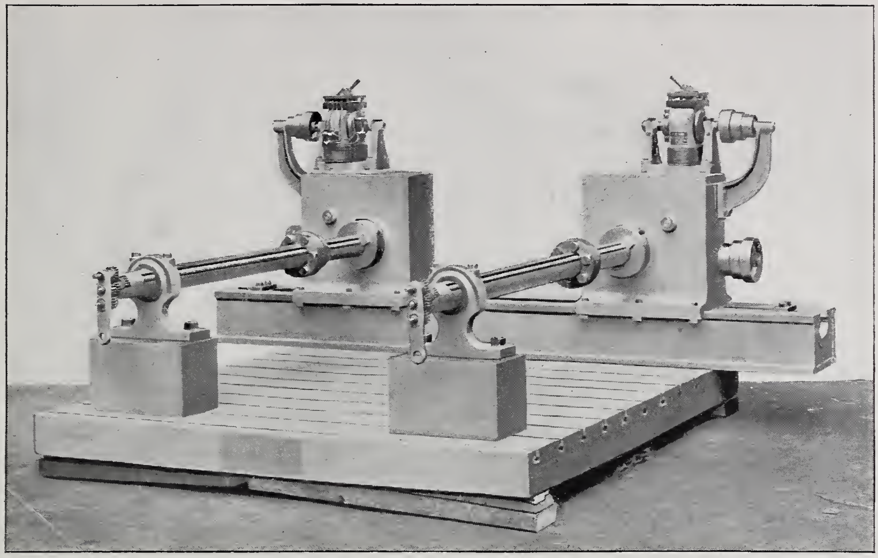
With the present machine tools the methods of long years ago have determined that their speed should be limited by the steps on the cone pulleys, and the speed of the tool cannot change from step to step without shifting of the belt which involves not only a certain loss of time on the part of the operator, but also marks a departure from the work which he has directly in hand and which he is disinclined to make unless it is very important for him to do so. It appears to encourage, even among the best operators, the tendency to "let well enough alone;" but in these days of shop competition, when it is imperative that the best results should be obtained with the least expenditure, "well enough" is rarely the best that can be done.



A LATHE WITH A BULLOCK MOTOR MOUNTED IN THE HEADSTOCK

Now the enterprising producer will look at this new form of energy to see if he cannot find any change to be made in the old familiar machine factors that will enable him to more closely approach the "best that can be done," and it appears from results so far obtained that such opportunity lies in applying individual electric motors to the tools, the motors being so arranged as to permit of their speed being varied within any range that the operator may desire. The significance of this is of the greatest importance to manufacturers, because it appears that they will be able to produce with a given factory force and equipment, the largest product and the best quality. Increasing the product with a fixed force means a larger return for the same pay roll; increasing the product with a fixed equipment means a larger return on a given investment; so that to the manufacturer the effect of a given form of power, for operating his tools, upon the rate of the production of those tools, is undoubtedly the most important factor in the consideration of the general subject of power distribution for industrial establishments.

Now, if it be true that the effect of the speed upon the product is an important consideration, the question arises,—Can this desired range of speed be obtained, and what degree of variation is possible?

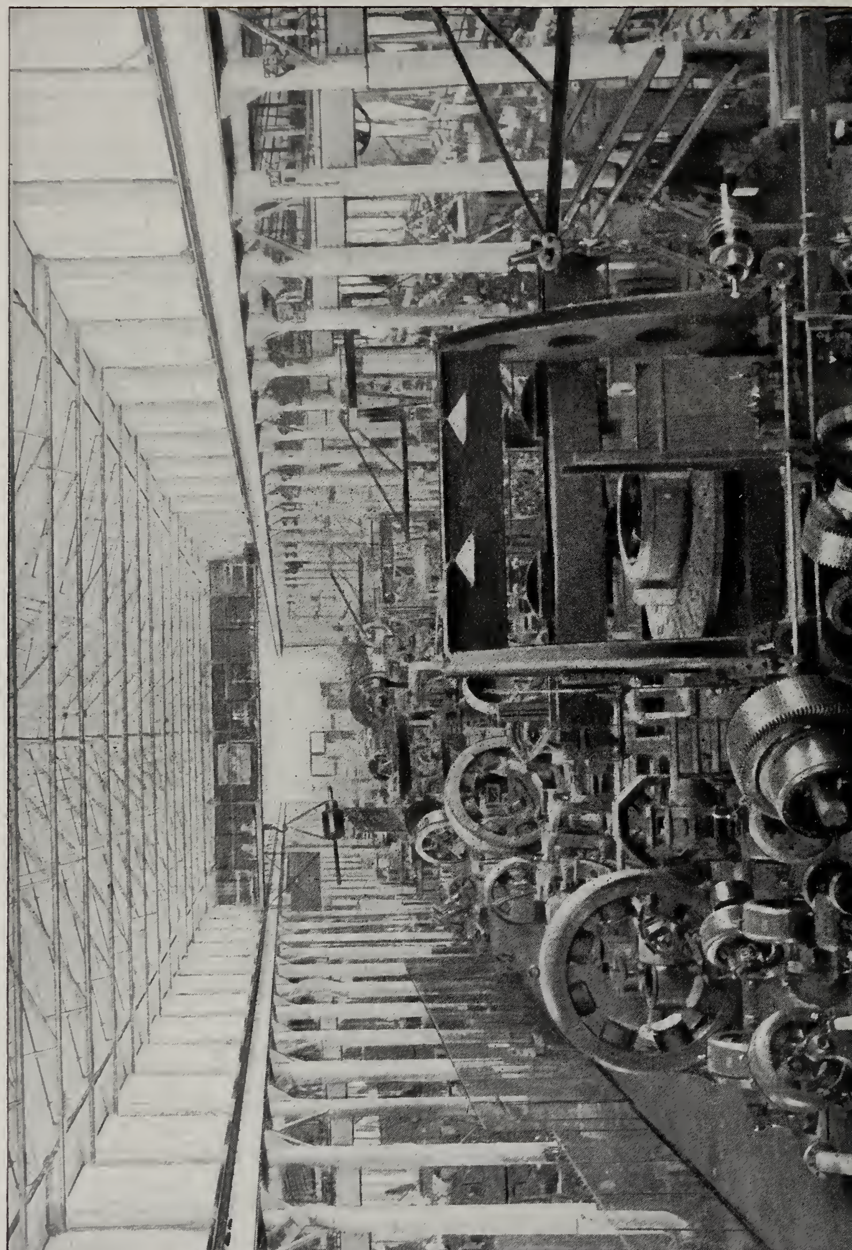


AN ELECTRICALLY DRIVEN HORIZONTAL DOUBLE BORING MACHINE FOR BORING VALVE BOXES. BUILT BY MESSRS. GREENWOOD & BATLEY, LTD., LEEDS, ENGLAND

It is not the purpose here to go into a technical discussion of this matter; it is sufficient to say that there are successfully operating, in a wide variety of industrial and other establishments, motors directly applied to tools and other machines that are capable of running continuously at any one of a number of speeds within such range as may be desired, and these motors may be made to operate at a constant torque and with the highest efficiency that could be expected from a power producer involving the general characteristics of the electric motor; that is to say, that while the efficiencies of the motors themselves may, at these lower speeds, be somewhat less than when the motor is running at its rated speed, yet there is no useless waste of the electric energy in rheostats and other current-consuming devices which were formerly used to cut down the speeds of the motors.

The methods used to obtain these desirable results may lie in the direction of generating the current at the source of supply at different potentials, corresponding to the speeds desired at the motors, or else by varying the torque conditions within the motors themselves to suit these various speeds, or such other methods as provide for an efficient control of the motors. Such systems are now to be found in successful operation, and what is more significant is the ease with which these various speeds can be obtained. A simple controller, giving, under ordinary circumstances, a choice of ten or twelve speeds, comes immediately under the hand of the operator, and if the incentive be there to cause him to produce the best results, he will, by the law of elimination, select that speed which will give the greatest amount of product of the best quality. Workmen have an abhorrence of fussing. If a man shifts a belt to one set of cones in the hope that he may find a speed better adapted to his work, and is disappointed, he fears possible unpleasant comments by his associates, while he may be a very conscientious workman; but if he can adjust his work without attracting attention and without causing him an effort, he is enabled to work a great improvement in the efficiency of the tool, the quality of the work, and the speed with which it may be produced.

Just what this improvement will

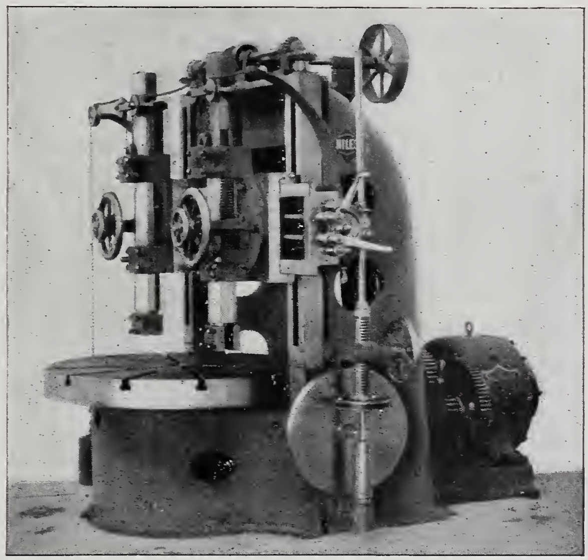


THE SHOP OF THE CROCKER-WHEELER COMPANY, AMPÈRE, N. J., U. S. A. ANOTHER EXAMPLE OF INDEPENDENT ELECTRIC MOTOR DRIVING

amount to depends entirely upon each individual case, but if we consider the general run of machine shops, and it is assumed that the quantity of the product can be increased, say, 10 per cent., due to improved speed conditions, it will be readily seen how important this phase of the general proposition is, because this percentage of increase, when figured on the total value of the product, not only places an amount to the credit of the direct-connected electric motor that promises to cancel its first cost probably in two years, if not in the first year, but also provides a factory equipment which has many other collateral advantages.

Perhaps the question arises as to whether the electric motor has effectually won a claim to the complete confidence of the manufacturer who is operating on a large scale and who cannot be bothered with undetermined factors. Apropos of this it need only be said that for the past fifteen years the electric motor has been recognised as a practical power device, and during these years many improvements have been made in the details of its construction, so that now it can scarcely be recognised as being the same machine.

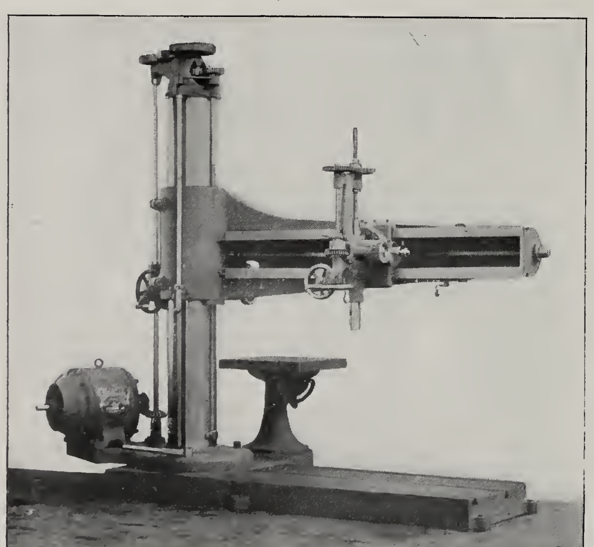
To-day an electric dynamo in its form of either "generator" or "motor" is an efficient machine showing no evidences of distress under normal load, or even under heavy over-loads, and such defects in construction as may occur are readily located and repairs made with the greatest ease. The machines are compact in form, can be had for any speed between 50 and 2500 revolutions, depending on the size, and of any capacity that the purchaser is ready to pay for. The depreciation from mechanical causes has been reduced to small quantities which compare most favourably with other mechanical devices of a like nature. As to construction from an electrical standpoint, the manufacturer has come to understand the nature of the materials best adapted to stand high temperatures without lowering the integrity of their insulating qualities. And, furthermore, the mechanical construction of these electrical parts is such as to permit of any one part being quickly removed and another one substituted without disturbing the unaffected contiguous parts. All this tends to make a device with which practical operators are quite willing to become shopmates. A shop superintendent, whose establishment is equipped entirely with direct connected motors, states, in reply to the question whether all tools in a conglomerate machine shop should have individual motors:—"The result and advantages of a shop operated by individual motors are that more perfect speed control can be obtained, and the operator has always at his command the full limit of his machine, and simply by moving a lever he stops, starts or reverses, and also gets a wide range of speed without any other movement on his part



AN ELECTRICALLY DRIVEN BORING MILL MADE BY THE NILES TOOL WORKS CO., HAMILTON, O., U. S. A.

than that to control the lever, which can be arranged so as to bring it immediately under his hand. Further, when no work is being done, no power is being consumed."

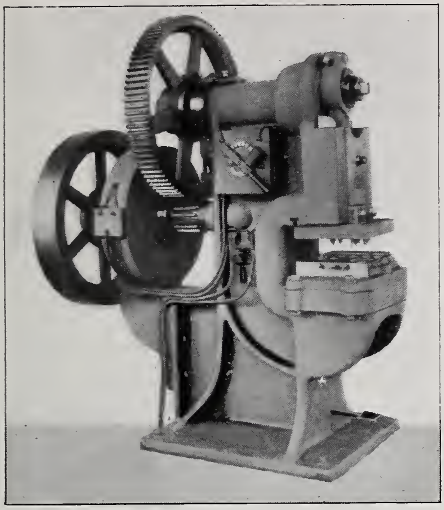
This, then, brings us to the second consideration, that of the efficiency of the general system. In an able paper before the American Society of Mechanical Engineers by Professor C. H. Benjamin, it was pointed out that in six shops taken at random where heavy machine work was done an average of 62.3 per cent. of the power produced was used in driving the shafting; in one case it was found to be as high as 80 per cent. It must be borne in mind that this loss is a constant load, independent of the amount of useful load upon the power-producing plant; and it is fair to assume that the friction represented by this useless consumption of power is largely increased when the useful load is put on. With electricity, however, it might be said that the loss due to transmission decreases with the load. Prof. Benjamin's paper also did not give the losses due to belt slippages, and it is well to bear in mind the slowing down of tools which is occasioned by this slippage and which, in the long run, must represent a very considerable decrease in the actual output of any establishment.



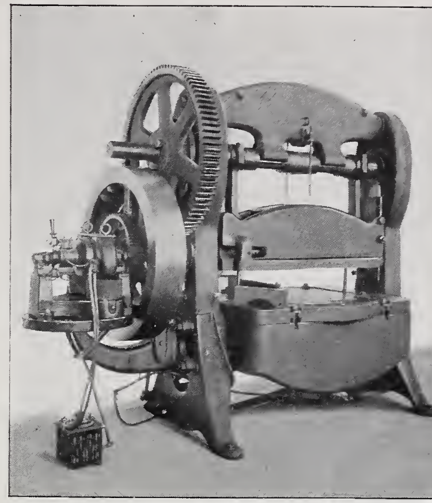
AE ELECTRICALLY DRIVEN RADIAL DRILL

The small amount of power necessary to operate an establishment in which the tools are operated by individual motors has proved to be astonishing. Such cases as a printing establishment with a motor on each press, the aggregate rated capacity of which, together with the other connected load, equalled 127 H. P., carries this load during the light hours of the day on a 25 K. W. generator. In the shop illustrated on page 149 the aggregate capacity based on the ratings of the motors, to which is added the electric lighting of the shop, the electric crane, etc., amounts to 177 H. P., while the average load (current supplied by the generator), as shown by a recording wattmeter, is but 27 H. P. It is commonly found that in plants in which merely the main belting is displaced by electric motors, the power saved is sufficient to operate all the electric lights of the establishment, and where the subsidiary shafting and belting are done away with, a substantial saving in the coal pile is effected in addition to obtaining electric light.

As regards the third consideration, viz., general appearance and morale of an establishment, the views of electrically operated shops shown on pages 159 and 162 perhaps tell their own story better than words. The perfect ventilation, free distribution of light, and cleanliness produce a most striking effect, and to this is added in the shop itself the absence of noise. In one of the shops absence of belts made it possible to use an overhead hot air supply system for winter, and the same apparatus supplies cold air in summer. The tools are all painted with an aluminium paint, and it



A STAMPING PRESS DRIVEN BY A BULLOCK ELECTRIC MOTOR



ANOTHER PRESS DRIVEN BY A CROCKER-WHEELER MOTOR

is the ambition of each workman to keep his machine cleaned up and in the best possible condition. It has been found that the distribution of light, both natural and artificial, can be accomplished most advantageously, shadows being conspicuous by their absence. It has been possible to place large lathes and other tools in the middle of the shop without reference to head-room, so that the scope of usefulness of the electric crane is largely increased, and small hand cranes become available for use in the bays.

The tools can be set without reference to any particular alignment, and can be arranged in the order taken by the work in its progress towards completion. Portable tools can be brought to the heavy work, and any re-arrangement of lay-out can be made at a moment's notice without any other consideration than that to obtain the best results from the standpoint of the producer's convenience. In such a shop not only are the tools arranged to the very best advantage, and with a possibility of working all the auxiliary devices of the shop to their utmost usefulness, but the operator is encouraged to produce the best results, because he has within his hands a control of the tool that covers its full capacity. The surroundings are such as to give him plenty of light and ventilation and a general air of cleanliness is apparent, all of which is obtained with the highest economy that has yet been attained for power transmission in industrial establishments of the common class.

ELI WHITNEY

THE INVENTOR OF THE COTTON GIN

A BIOGRAPHICAL SKETCH

AS the founder of the modern system of interchangeable manufacture of machinery parts which, at the present time, has a special significance in the competition for the world's market for engineering workshop products, Eli Whitney will always figure prominently in engineering history, though he is, perhaps, most widely and popularly known as the inventor of the cotton gin.

He was born at Westborough, Worcester County, Massachusetts, December 8, 1765, and gave indications of his mechanical genius at an early age. His father had a workshop with a variety of tools, which Eli learned to use while still very young. He was always making something in the shop, and much preferred this occupation to working on his father's farm.

When he was fifteen or sixteen years of age he engaged in the manufacture of nails, which at that time were in great demand. With the aid of a few simple tools he carried on this occupation for two winters, and when, later, the business was no longer profitable, he turned his attention to making long pins for fastening on women's bonnets, which were then in fashion, and also manufactured walking-sticks of peculiar neatness.

Even at the early age of fourteen he had acquired a large fund of general information and was particularly apt at figures and arithmetic, but as he grew older he felt the need of a more liberal education.

After overcoming many obstacles, he, therefore, entered Yale College, in May, 1789. During his college course he devoted more attention to mathematics and mechanics than to the ancient classics, and he also found opportunities to exercise his mechanical ingenuity.

Soon after taking his degree, in the autumn of 1792, he entered into an engagement to act as teacher in a Georgia family, intending to study law at the same time. But when he arrived at Savannah he found that another teacher had been employed in his place, and he was, therefore, glad to accept the hospitable offer of Mrs. Greene, the widow of General Nathaniel Greene, to make his home at her house while pursuing his legal studies.

Not long afterwards, a large party of gentlemen, consisting principally of officers who had served under General Greene in the American Army, came from Augusta and the upland part of Georgia to visit Mrs. Greene and her family. In the course of conversation upon the state of agriculture among them, great regret was expressed that there was no economical means of separating the lint of the upland or green seed cotton from its seed, as much land which was unsuitable for the cultivation of rice would yield large crops of cotton. Separating one pound of the clean staple from the seed was a day's work for a woman, and until some machine could be devised which would greatly facilitate the process of cleaning, it would not pay to raise cotton for the market.

While they were thus talking, Mrs. Greene recommended them to apply to

her young friend, Mr. Whitney, who, she said, could make anything, in proof of which she showed them a frame for making embroidery, and a number of toys which he had lately constructed or repaired. She then introduced the gentlemen to Whitney himself, and though he modestly disclaimed the possession of any mechanical genius, their conversation made a deep impression upon him and gave a new turn to his thoughts.

He got some cotton in the seed and began experiments in a machine for cleaning it, in a room of Mrs. Greene's house. He was greatly hampered by lack of proper materials and tools, but he set resolutely to work and continued at his self-appointed task all through the winter until his machine was so far completed as to leave no doubt of success.

In a letter, written November 24, 1793, to Thomas Jefferson, then American Secretary of State, to whom he had applied for a patent, he gives the following short history of his invention:—

"Within about ten days after my first conception of the plan, I made a small, though imperfect, model. Experiments with this encouraged me to make one on a larger scale, but the extreme difficulty of procuring workmen and proper materials in Georgia prevented my completing the larger one until some time in April last. This, though much larger than my first attempt, is not above one-third as large as the machines may be made with convenience. The cylinder is only two feet two inches in length, and six inches in diameter. It is turned by hand, and requires the strength of one man to keep it in constant motion."

Whitney's machine, which became popularly known as the cotton gin, has been improved in the course of the past century in many of its details, but the essential parts are as he left them.

PHINIZY'S OLD MILL, FOUR MILES FROM AUGUSTA, GA., U. S. A., WHERE WHITNEY'S COTTON GIN WAS FIRST OPERATED

"The main features consist of a cylinder, generally about four feet long and five inches in diameter, upon which is set a series of circular saws, about half an inch apart, and projecting about two inches above the surface of the revolving cylinder. A mass of cotton in the seed, separated from the cylinder by steel bars or grating, is brought into contact with the numerous teeth on the cylinder. These teeth catch the cotton while playing between the bars, which

allow the lint but not the seed to pass. Underneath the saws is a set of stiff brushes on another cylinder revolving in the opposite direction, which brush off from the saw teeth the lint which they have just pulled from the seed. The remaining feature is a revolving fan for producing a current of air to throw the light and downy lint thus liberated to a convenient distance from the revolving saws and brushes.''

Phineas Miller, a Connecticut man and a graduate of Yale, who afterwards married Mrs. Greene, was at this time an inmate of her house, and took a lively interest in the cotton cleaning machine. He formed a partnership with Whitney for the purpose of bringing out the invention, and soon afterwards Whitney went back to Connecticut, where he was to perfect the apparatus, obtain a patent, and manufacture the machines. Before this, rumours of the new apparatus had spread through Georgia and caused great excitement and curiosity. So intense was the desire to see the wonderful invention that before the larger model was finished the building in which it was being constructed was broken open by night and the machine carried off, and before Whitney could obtain a patent many machines were in successful operation, constructed with small deviations from the original, in order to evade legal penalties.

This was the beginning of a long series of troubles and discouragements for Whitney. His workmen became ill, his shop at New Haven, with his machines and papers, was burned, and, worst of all, a report came from England that the manufacturers there condemned the cotton cleaned by his machines on the ground that the staple was greatly injured. These prejudices, however, were happily cleared away, and there arose a great and increasing demand for cotton cleaned by Whitney's gin; but by this time his patent rights were so encroached upon as to be almost valueless. Numerous lawsuits against infringers were instituted, but it was many years, and after the death of his partner, Mr. Miller, before Whitney could obtain justice. It was on the occasion of the favourable issue of one of these suits in the United States Court, in Georgia, in December, 1807, that Judge Johnson rendered his celebrated decision, in the course of which he said:—

'' With regard to the utility of this discovery, the Court would deem it a waste of time to dwell long upon this topic. Is there a man who hears us who has not experienced its utility? The whole interior of the Southern States was languishing, and its inhabitants emigrating for want of some object to engage their attention and employ their industry, when the invention of this machine at once opened views to them, which set the whole country in active motion. From childhood to age it has presented to us a lucrative employment. Individuals who were depressed with poverty and sunk in idleness have suddenly risen to wealth and respectability. Our debts have been paid off. Our capitals have increased, and our lands trebled themselves in value. We cannot express the weight of the obligation which the country owes to this invention. The extent of it cannot now be seen.''

In 1801 the legislature of South Carolina voted to buy the patent rights of Miller & Whitney within that State for fifty thousand dollars, and after some vexatious delays the partners received the money. The next year the State of North Carolina laid a tax, to be continued for five years, upon every cotton gin working within its borders, and the proceeds, after deducting the expenses of collection, were paid over to the patentee, in return for which he made over his rights to the State. Tennessee likewise passed a law taxing cotton gins for the benefit of the inventor, but the Act was soon suspended.

By the time Whitney had secured a favourable decision in the courts the term of his patent had nearly expired, and though he afterwards, in 1812, made application to the United States Congress for a renewal, his petition was not granted. Taken all in all, his cotton gin brought him great fame, but lit-

tle fortune, for the money he did derive from the sale of his patent rights was swallowed up in lawsuits and other great expenses.

Feeling uncertain of the financial success of his cotton gin, Whitney devoted himself to a new enterprise in 1798. On January 14 of that year he concluded a contract with the United States Government to furnish ten thousand muskets within a little more than two years. This was a very bold move on Whitney's part, for this new business had to be built up from the very foundations. He had to borrow capital, erect a factory, make tools, gather his raw materials together, and instruct his workmen. Moreover, he was himself inexperienced in this branch of manufacture. But his ingenuity, good sense, pluck, and perseverance carried him over all obstacles; and though, owing to unforeseen difficulties, he had to get an extension of time, his contract was fulfilled to the entire satisfaction of the government.

His business being now firmly established, he was able to undertake new contracts for arms with the United States and the State of New York with profit to all parties concerned. It may be interesting to record some remarks on Whitney's methods of manufacture by a gentleman who was personally and intimately acquainted with the subject:—

"The several parts of the musket were, under this system, carried along through the various processes of manufacture, in lots of some hundreds or thousands of each. In their various stages of progress they were made to undergo successive operations by machinery, which not only vastly abridged the labour, but at the same time so fixed and determined their form and dimensions as to make comparatively little skill necessary in the manual operations. Such were the construction and arrangement of this machinery that it could be worked by people of little or no experience, and yet it performed the work with so much precision that when, in the later stages of the process, the several parts of the musket came to be put together, they were as readily adapted to one another as if each had been made for its respective fellow. A lot of these parts passed through the hands of several different workmen successively (and in some cases returned several times, at intervals more or less remote, to the hands of the same workman), each performing upon them every time some single and simple operation, by machinery or by hand, until they were completed.

"Thus Mr. Whitney reduced a complex business, embracing many ramifications, almost to a mere succession of simple processes, and was thereby enabled to make a division of the labour among his workmen, on a principle which was not only more extensive, but also altogether more philosophical than that pursued in the English method. In England, the labour of making a musket was divided by making the different workmen the manufacturers of different limbs, while in Mr. Whitney's system the work was divided with reference to its nature, and several workmen performed different operations on the same limb.

"When Mr. Whitney's mode of conducting the business was brought into successful operation, and the utility of his machinery was fully demonstrated, the clouds of prejudice which lowered over his first efforts were soon dissipated, and he had the satisfaction of seeing not only his system, but most of his machinery, introduced into every other considerable establishment for the manufacture of arms, both public and private, in the United States."

These labours of Whitney were of the greatest value to the public interest. A former Secretary of War of the United States admitted, in a conversation with the inventor, that the United States Government was saving twenty-five thousand dollars a year at the two public armories alone, by his improvements, and this estimate is believed to be far below the true one.

Nor was the utility of Whitney's labours limited to the particular business in which he was engaged. Many of the inventions which he made to facilitate the manufacture of muskets, were applicable to most other manufactures of

iron and steel. To many of these they were soon extended and became the nucleus around which other inventions clustered. And at the present day Whitney's beneficent influence may be recognised in nearly every factory and machine shop in the United States.

It was characteristic of Whitney's ingenuity and humane disposition that his attention was directed even to the mangers for his cattle, and to their fastenings. It is said that the latter were so contrived that, by means of a small weight at the end of the halter, the animal could always move his head with facility, but could not draw out the rope so as to become entangled in it, nor could he easily waste his hay.

The domestic arrangements of Whitney's house also bore testimony to the ingenuity which he showed in common things, as well as in those more important. The several drawers of his bureaus, for instance, were locked by a single movement of one key, of a peculiar construction, and an attempt to open any drawer except one would prove ineffectual, even with the right key, which, however, being applied in the proper place, threw all the bolts at one movement.

He was a pioneer in another field which is just beginning to be properly cultivated. His factory was situated near New Haven, on the banks of a little river, and, not satisfied with utilitarian perfection alone in his shops, he devoted his attention also to their æsthetic side, and made them and the neighbouring cottages of his workmen harmonious parts of a picturesque landscape.

In person, Mr. Whitney is said to have been considerably above the ordinary size, of dignified carriage, and of an open, manly and agreeable countenance. He was a man of broad culture, interested in all the great questions of the day. The advantage of a liberal education to a man of mechanical invention was very conspicuous in his case, for his college training not only fitted him to rationally enjoy his moments of leisure, but it helped directly to guide his inventive faculty and to lead him to the highest success in his life work.

He had an extensive acquaintance among the leading men of his time, and was universally esteemed. He took great pleasure in the society of his friends, and he was a great favourite with children.

Happy in his home and his family relations, his latter years were blessed with well-earned prosperity. After a lingering and painful illness, borne with great fortitude and resignation, he died on the 8th of January, 1825.

AMERICAN MACHINE TOOLS AND METHODS

A BRITISH OPINION

By Ewart C. Amos, M. Inst. M. E.

DEALING at length, recently, with the subject of machine tools, in a paper before the British Society of Engineers, the author stated it to be his opinion, after careful inquiry, that with the exception of certain leading firms, who are turning out machines equal to any of those imported, the majority of tool manufacturers in Great Britain are not keeping pace, either in quality or design, with the American and other tools now being imported, and the very fact that so many British tool manufacturers are buying for their own use considerable numbers of American machines, proves conclusively, without other evidence, the style and quality of machine the Americans are sending over.

It might be well to say here that the author is neither interested in, nor connected with, any American firm of tool makers, and to add, that notwithstanding the conclusion already expressed, he is still of opinion that it lies in the power of the majority of the British makers to turn out work which shall compare favourably with the best imported article; but to do this means considerable alteration from the present method of manufacture, besides the destruction of large quantities of old and obsolete patterns. This, no doubt, would be a sore point with many, as the old idea of what once worked well can never work better, and what was good for our forefathers should be good enough for us, is so powerful an argument with many that nothing short of better machines actually coming into our markets and ousting old and inferior designs would have brought about the change which is gradually taking place. It, therefore, becomes an open question whether the advent of the foreign tool is not a blessing in disguise, especially at the present time, when, owing to the comparative scarcity of tools, our own manufacturers, who are in need of increased productive facilities, are able to add to their plant by buying American machines. This advantage is of a dual nature, as it enables them to appreciate the best points of the foreign article through practical use, and at the same time to introduce in their own manufactures similar advantages.

It must not be forgotten that very many of the ideas embodied in American machines originated in Great Britain, but American makers have perfected or modified them, and, having given great attention to detail, have produced a machine which is practically a great advance on the original. For instance, the author believes it is a fact (although he is open to correction) that the boring mill was first made in Great Britain, although it is generally looked upon as of American design. Doubtless American makers have added improvements, although some British-built machines require a lot of beating.

The most striking difference between the two makes, which is in favour of the American, is in the design, nor can it be said that American machines are wanting either in accuracy or finish. Doubtless there are a number of these machines which are not altogether sat-

isfactory, but we do not see many of them over here, the better class only being imported, and it will hardly be disputed that the American tool, as a whole, is a well-designed and carefully proportioned machine, adapted to turn out the maximum of work with the minimum of labour. Tool-makers are, in a way, guided by the requirements of their customers, and in the absence of a different class of tool being asked for, they continue to supply the same old thing. But the Americans, having studied the question carefully (the high wage-rate they have to pay being a strong incentive), have introduced here an improved class of machine, and have proved to us the great saving effected by its use. The result is that British tool-makers are rapidly following suit, and, it may be said with pleasure, they are in some cases going one better. But the progress is slow, and in the meantime we are to some extent losing our market and have to face a competition which hitherto had no existence,—a competition, moreover, which is likely to be a serious matter in the near future. It is not disputed that our tool-makers have been for some time, and still are, exceedingly busy, the boom in the trade being one of the largest on record; but unless the future should prove very different from the past there will be a slump to follow as soon as our abnormal Admiralty and other government contracts have been completed.

The cycle boom, which created a demand for a special type of tool, and called into existence several new firms who devote their energy almost exclusively to cycle tools, has been on the wane for some little time, and has encouraged the American manufacturer also to seek other clients and extend his connection. One thing in particular to which the author wishes to call attention is the fact that American tool-makers go in for a few specialties in which they excel, and do not attempt to make every class of tool, which is such a prevalent practice with our own makers. Without elaborating this point, it may safely be said that it goes a long way to explain how it is that American firms can deliver their machines in Great Britain at a price which competes with the home products.

Of the lighter class of tools, hand tools, etc., the American make is undoubtedly superior to the British, and the competition in the larger machines is getting very keen. Then, again, where the American makers gain so much is in their method of manufacture. Their practice is to put in hand at least a dozen machines at the same time, stocking what is not to order, while British makers build, as a rule, to order only.

Their system enables them to use elaborate jigs and templates, which secure accuracy, economy and rapidity in manufacture, but does not pay in the case of one machine. Having set a tool to mill, plane or drill a certain piece of work, it is evidently economical to be able to machine, say, a dozen or fifty of the same kind before removing the jigs and resetting the machine for other work.

These are points which make it possible for Americans to sell their machines at prices approximating to our own, and often of better quality, notwithstanding the fact that they are paying a higher wage-rate, and have freight and other expenses to add. Knowing the large business which agents are doing in American machinery on this side, it is useless to disguise from ourselves that they are a factor to be dealt with from a competitive point of view. This is now recognised, but at the same time it is to be hoped that the great strides made in mechanical engineering during the last few years will call for the use of so much machinery as to make room for both classes of tools, promoting, at the same time, a healthy competition.

Current Topics

Of the inventive ingenuity of Eli Whitney, of whom, by the way, a brief biographical sketch is given in this issue, Professor Silliman, in some reminiscences published in 1846, cites several interesting examples. In the summer of 1808, for instance, he tells, Whitney was applied to for tubes of block tin, for the purpose of drawing through an innocuous metal the soda water, highly charged with carbonic acid gas, which was then just beginning to be known. Lead and copper tubes were rejected on account of their poisonous properties, and there were then no facilities in the United States for constructing the tubes that were desired. Whitney accomplished the object, with his usual precision. The tubes were required to be many feet long, and strong enough to resist a heavy pressure. He caused a mould to be constructed of cast brass, in two parts, each containing, for about two feet in length, one-half of the cylindrical cavity corresponding to the desired tube. When the parts of the mould were accurately fitted and screwed together, they contained the entire cylindrical cavity between them, and to secure the duct through the tube a polished steel rod, of the proper size, and made very slightly tapering, was fixed in the centre and the melted metal was cast around it; the rod, being terminated by a ring, was easily knocked out. The separate parts of the tube, thus produced, were then joined into one, by having the contiguous ends of two of them brought longitudinally into contact, and included in another mould, containing an enlarged cavity, into which melted tin was poured. The duct was preserved by a steel rod passing through it as before, and thus the joint was perfected by a knob of metal, which at once united the two tubes into one, and gave them great additional strength. Whitney did not state that this method was original, but up to that time there had, so far as is known, been no similar method of casting block tin tubes.

Among the many industries connected with the iron and steel trades, there is one survival from former times in England which is of great interest. This, according to the *Journal*, of the Franklin Institute, is the mail chain armour manufacture in Walsall. J. W. Hawkins & Co., Limited, who contract with the Government for the supply of spurs, bits, stirrups, harness, buckles, chains, etc., also supply mail chain jackets and other steel productions for use in India, Central and South Amer

ica, and other countries. These jackets of mail, which weigh from 15 to 18 pounds, are said to be worn by army officers, and sometimes by Indian native princes, and are made of steel rings of 3/8-inch diameter. It takes about 3000 rings to make a square foot of armour. These rings are formed out of soft steel wire of 14, 15, 16 or 17 B. W. G., which is revolved around mandrels 4 inches long, and of the same diameter as the rings required, each mandrel taking about 6 feet of wire, which is subsequently divided by a hand saw. Hardening is accomplished by putting the rings upon trays and plunging them, when red-hot, into oil, after which they are polished in revolving drums.

AMONG oddities in steamship propulsion the United States steamer *Alleghany*, of more than half a century ago, furnished a conspicuous example. Rear-Admiral G. E. Belknap, U. S. N., in referring to her some time ago, in a lecture before the United States Naval War College, described her as an iron paddle-wheel vessel, with the wheels fitted horizontally into recesses of the hull below the water-line. The idea was to protect the wheels from the enemy's shots, but the back-water in the confined recesses and the boring effect of the shafts upon the lower bearings made short work of the theory. Scarcely more than 5 knots could be got out of the vessel under average conditions, and almost constant repairs of the lower shaft bearings were necessary. After considerable experimenting, at great expense, the *Alleghany* was converted into a receiving ship, thus putting a comparatively inglorious end to her career.

CHLORATE of potash has always been regarded by manufacturers and chemists as a non-explosive, and hence little care has been taken in handling and storing it. A recent explosion, however, at a large chemical works at St. Helens, in England, seems to disprove this view. A storehouse containing about one hundred and fifty tons of chlorate in the form of both powder and crystals took fire, and almost immediately after the falling in of the roof an explosion of terrible violence occurred, the shock being felt over a distance of twenty miles. The chlorate works were entirely demolished. A large gas holder of the city gas works, containing 250,000 cubic feet of gas, was burst and the gas ignited, and eight hundred tons of vitriol were poured into the streets of the town by the wrecking of ten vitriol chambers in a neighbouring alkali works. Houses were unroofed, and in the main streets of the town, a quarter of a mile away, nearly every plate-glass window was demolished. A theory accounting for the explosion, advanced by Mr. J. B. C. Kershaw, in the *Engineering and Mining Journal*, at the time, was that it was due to the sudden and practically simultaneous liberation of all the oxygen from such a mass of chlorate, combined with the restraining influence of the kegs (the chlorate was packed in kegs of one hundredweight each), and possibly also helped by the presence of much charred wood and the dense volume of smoke. Whatever is the true theory, however, it would seem that the prevalent belief in the non-explosiveness of potassium chlorate must be modified.

FOR ringing large bells the ordinary electric bell action, as experience has shown, is unsuitable, not only because of the relatively great amount of energy necessary in the required large sizes of electro-magnets in order to accomplish any appreciable mechanical result, but also on account of the trouble from the sparking of the contact maker. Some interest is, therefore, attached to a recent German description of a number of large electrically operated bells in which a small electric motor does the work. The motor drives a worm and wheel gear, and a pinion on the axle of the wheel is geared into a large spur wheel on which there are four projecting bosses. As these revolve they engage with a ratchet on a lever, at the end of

which is a wire to which the hammer of the bell is attached. The lever is fixed in such a position that the hammer of the bell almost touches the gong. It is then drawn away by the gear described above, and on being released, the hammer strikes the gong, giving a very loud signal. These bells, it is stated, are being used largely for railway signalling and for sounding alarms at level crossings. They are also employed at manufacturing works for time-signalling purposes. As the motors are not run for any length of time they require very little attention.

THAT fire cannot exist where oxygen is lacking is an obvious truth, and it is on this that the success of the various fire-extinguishing powders depends and also the efficient operation of steam jets, which latter have long been recognised as good fire-fighting media under certain conditions. Aqua ammoniæ has recently been added to the list of these extinguishers, as would appear from an item telling of a case where the vapours of a tank containing 50 gallons of gasoline caught fire in the linen room of a laundry. The room was instantly a mass of living flames, but a gallon and a half of ammonia water, thrown into it, completely and almost immediately extinguished the fire. The ammonia was in a glass demijohn in an apothecary's shop next door to the laundry, and was thrown into the room by the druggist as an experiment. To use his own words in reporting the circumstance, "the effect was instantaneous, torrents of black smoke rolled upward in place of flames, and in a moment every trace of fire was gone."

APROPOS of the recently much spoken of practice of oil-sprinkling on railways which has been adopted on portions of several lines in the United States with very satisfactory results, it should be observed that the oil treatment not only checks the nuisance to passengers from dust where sand and gravel ballast is used, but also reduces the chances of hot boxes, tends to prevent the growth of weeds, and reduces the heaving action of frost. According to a paper recently read before the Roadmasters' Association of America by Mr. E. E. Russell Tratman, the oil used is a residuum of crude petroleum, having a high fire test, low gravity and only a faint smell. The first application requires about 2000 gallons per mile, and about 500 to 600 gallons per mile per year will suffice to keep the ballast dustless, after tie renewals, etc. The sprinkling train is run at a speed of about 3½ to 4 miles an hour. In front is a flat car, fitted with a 2-inch pipe across between the rails, and a 2-inch swinging pipe on each side, all these pipes having slots in the under side. The supply is brought from a tank car to these pipes by a 4-inch main, and the regulating valves and the swinging pipes are all controlled from levers or handles on the flat car. With the pipes swung out, a width of 15 to 20 feet of roadbed may be sprinkled. The rails are protected by shields.

BY sprinkling its roadbed with oil and burning coke, instead of coal, in its locomotives, the Boston & Maine Railroad is aiming at giving its passengers as clean a service as that of electric railways, if, indeed, not a cleaner one, for dust, whirled up from the roadbed, is in many cases an annoying accompaniment of electric travel. The extensive operations at Everett, Mass., near Boston, of the New England Gas & Coke Company, in which the coke is virtually a by-product and is sold as such, has made it available at about the same price as bituminous coal, and the Boston & Maine road accordingly has for some time been actively pushing the changing-over of its engines from coal to coke burners. In its suburban service thus far the results have been highly satisfactory, and the practice is to be extended so as to ultimately include also the freight service of the line, providing there will be no prohibitive change in the coke price, which, from present indications, would seem unlikely for some

time to come. Water grates were at first thought necessary in fitting up the locomotives for coke, owing to the intense heat of combustion; but the present practice is to lead a portion of the steam exhaust from the air-brake pumps across the front end of the ash-pan and let it escape underneath the ordinary grates from several ¼-inch holes. This simple bit of piping serves its purpose excellently, and for the return to coal burning it may be plugged or provided with a cock. The saving over the putting-in of water grates was considerable, not counting the interchangeability of the new arrangement for both coke and coal.

As it is the prevailing opinion with many engineers that a Portland cement mortar which has stood an hour or two has lost some of its strength, it is worth while to direct attention to the results of some tests recently made by A. S. Cooper, and detailed in a paper before the Franklin Institute, to determine to what this loss of strength amounted, if, indeed, there were any. Four large batches of mortar were mixed and briquettes were made by hand from each pile at intervals ranging up to eight and one-half hours after mixing. These were all carefully marked, stored away, and broken after one year. The results showed that the loss of strength after the eight and one-half hours' standing is practically nothing. In practical working with most Portland cement, if it becomes necessary for the mortar to stand for half a day even, no injury will result, according to Mr. Cooper, provided the precaution is taken to keep the mortar wet.

WHAT electrolysis from electric street railway currents will do in the way of water and gas pipe destruction is shown in a collection of instructive photographic reproductions accompanying a paper on the subject recently read before the Central States Water Works Association by F. A. W. Davis, of the Indianapolis, U. S. A., Water Company, and just issued in pamphlet form. Mr. Davis makes the interesting statement that in one case he found a 50-volt current coming from a water meter connection, and in another case the current was so strong that when the water pipe was cut in two a piece of iron of the thickness of a shovel, placed in the opening, was melted. In still another case the singular spectacle of a fire hydrant apparently on fire was seen. Gas had escaped from a street main, and, coming up around the fire hydrant, had been ignited by current from the trolley line, passing from the casing to the hydrant. In several instances a gas company found the stray currents so strong that when a pipe was separated the gas was ignited by the passing sparks and endangered the lives of the workmen. In two instances there were narrow escapes from setting fire to buildings near by.

THE greatest steam superheating plant in existence is said to be that of the Aachen Mining Company at their works at Rothe Erde, Germany. All the boilers are fitted with superheaters of the Schwoerer type, forty-two of which have been installed in the flues connected with a similar number of Cornish double-flue boilers, having aggregate heating surfaces of 47,363 square feet. Besides these an additional set of five large superheaters of the same type have been connected with a second group of twenty-four Cornish boilers, with a heating area of 26,910 square feet. An interesting fact connected with this plant is said to be the small loss of heat in the steam-pipes used for conveying the steam to a distance. This loss is at the rate of only 1° C. for each length of 42 feet of 24-inch steam-pipe, the total distance travelled by the steam being 1050 feet. Very careful tests, extending over three years of day and night working, have shown the saving in fuel by the use of this plant to be from 15 to 20 per cent.

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THE HONOURABLE CHARLES A. PARSONS

THE DESIGNER OF THE FASTEST STEAM VESSEL AFLOAT

CASSIER'S MAGAZINE

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THE SIMPLON TUNNEL

By Axel Larsen, M. Inst. M. E.

THE VILLAGE OF SIMPLON

AT Brig, in the Swiss canton of Wallis, the Jura-Simplon railway reaches its terminus, further progress having hitherto been barred by the Simplon giant. To pierce this vast mountain by a tunnel was for a long time considered a task before which even the boldest of engineers had recoiled. The difficulties of the undertaking were manifold. Not only was the length of the proposed tunnel exceptionally great, but it was feared that the very high temperature which would certainly be encountered midway in the tunnel, combined with bad air from poisonous gases and the fumes of explosives, would render continual working well-nigh impossible.

Somewhat of a sensation was, therefore, created in engineering quarters when it became known that Mr. Brandt,

A VIEW OF GOESCHENEN AND THE ST. GOTTHARD TUNNEL

of St. Gotthard tunnel fame, had undertaken to cut a tunnel through the Simplon, not only at a considerably lower cost than that of the St. Gotthard tunnel, but in half the time, the new tunnel to measure 19,731 metres (about 12 miles) in length, when completed, and becoming, therefore, the longest in the world.

The tunnel will establish direct communication between Paris and Milano, but without the drawback of the steep gradients which characterise the Gotthard line. While the Gotthard tunnel at its highest point is 1155 metres above the sea-level, the highest portion of the Simplon tunnel,—500 metres of horizontal track about midway, — will be only 705 metres above the sea, thereby enabling an ascending gradient of only .02 to be made on the north side and a descending gradient of .07 on the south side of the mountain. The entrance near Brig will thus be only 50 metres higher than the exit near Isella. This was favourable enough, but on account of the deeper level of the Simplon tunnel, —in places 2140 metres below the top of the mountain,—grave doubts were entertained as to a successful issue. From the thickness of the rock overhead it was calculated that about midway in the tunnel a temperature of about 105 degrees Fahr. would be reached, and who would risk to expose workmen to such a heat for several hours at a stretch, if, indeed, men could be found at all to work under those conditions!

During the tunnelling operations in the St. Gotthard, and shortly before the two approaching parties met near the middle, a maximum temperature of about 88 degrees Fahr. had been recorded, and as a large number of men and horses had then been disabled by the heat, how, it was asked, would it fare with those who had to work in a temperature eighteen or twenty degrees higher? Nevertheless, Messrs. Brandt, Brandauer & Co. signed their contract with the Jura-Simplon Railway Company for the construction of two tunnels, and guaranteed the completion of the main tunnel within 5½ years. No fixed time was stipulated for the completion of the second tunnel, which will be finished gradually, as an increasing traffic may require.

Mr. Brandt fairly astounded the engineering world, but astonishment was soon converted into genuine admiration on its becoming manifest with what rare

A SNOW GALLERY ON THE SIMPLON ROUTE

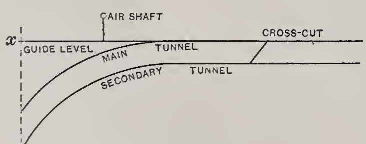
ingenuity and skill he had dealt with his subject. It was soon recognised that the duplex system, which was to be used here for the first time, was, indeed, the only means by which the Simplon could ever be successfully tunnelled, for the principal object of the second tunnel is to carry fresh air into the main passage during construction.

In the case of the St. Gotthard tunnel it had been proved that the dangerous period was at an end with the fall of the last intervening wall in mid-tunnel, and that from that moment there was an ample inflow of fresh air. Mr. Brandt, however, need have but little fear of any such period of danger, for the second tunnel serves him as a huge air pipe, which, as will be seen presently, draws a permanent and ample supply

THE SOUTHERN ENTRANCE TO THE SIMPLON TUNNEL

of fresh air into the workings. The second tunnel, which is to run parallel with the main tunnel at a distance of about 55 feet, is to be connected with the latter by winzes or cross-cuts 650 feet apart.

Excavations were begun at the points marked x and y in the accompanying sketch, that is, at the entrances to the "guide" and the secondary tunnels. The former was required for alignment purposes, and the latter had to be carried up to a certain point so as to complete the circuit of ventilation. This once accomplished, the main tunnel would take up the running.



THE TUNNELLING SCHEME

Both tunnels, main and secondary, run in parallel curves until the first cross-cut is reached. From there they follow a straight line until within a short distance of the Isella terminus, near Domo-dossola, where they again curve off in southeasterly direction so as to meet the proposed railway line from the south. A short piece of guide-tunnel is likewise cut at the Isella end, and is, like the one on the north side, a continuation of, and in a straight line with, the main tunnel.

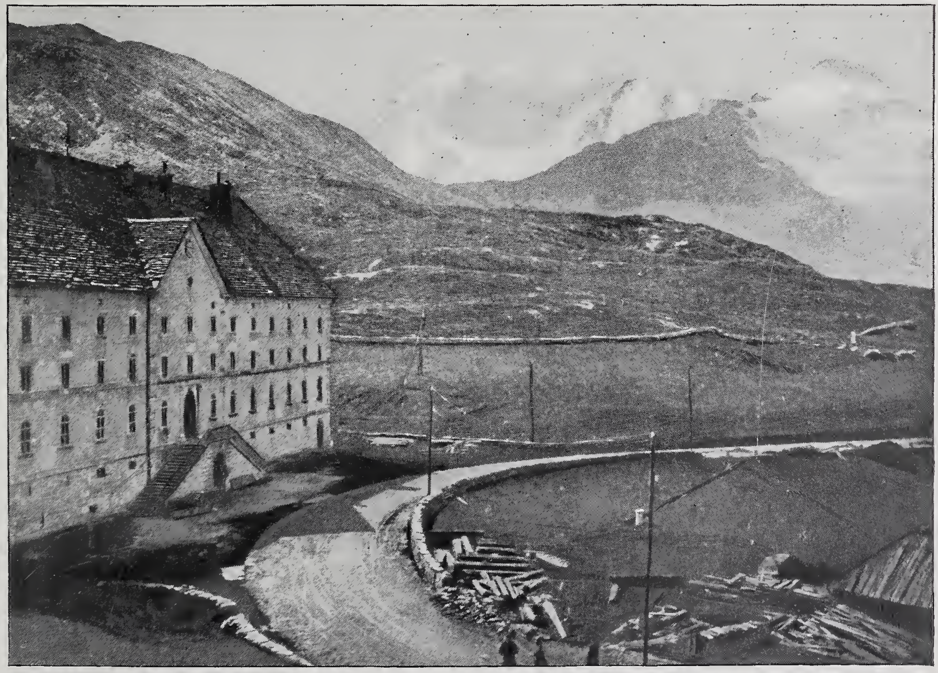
In order to further promote ventilation, a vertical air-shaft was excavated from the bottom of a short cross-cut to the surface of the mountain, which at that point is about 200 feet high. As soon as communication had been established between the two tunnels a log fire was lighted at the bottom of the air-shaft and the entrance to the guide tunnel was closed. As the heated air ascended and escaped through the air-shaft, fresh air was drawn into the workings and passed through the secondary tunnel and the first cross-cut. It will

be readily understood that as the work proceeds the air circuit may be correspondingly extended by the mere closing up of all the cross-cuts but the last; as an extra precaution it was, however, decided to place an engine in the intaking tunnel and to pump the air from there through long pipes right on to the working face. The method followed on the southern side is the same as that just described.

Turning to the tunnel-work proper, we find that one of the chief aims in the programme of the management is to work simultaneously in as many places as possible. Let us assume, for example, that the main tunnel had been driven 1000 yards, while a distance of only 600 yards had been reached in the second tunnel. In that case the work would still be vigorously continued in the former, regardless of the slower rate of progress shown in the latter tunnel. In order to help the second tunnel along, without, however, interfering with the work in the main tunnel, the winzes would in due course be cut across to the line of the second tunnel, the driving of which, in its turn, would be proceeded with in both directions, *i. e.*, forwards and backwards.

Again, should the excavation make more rapid strides in the secondary tunnel than in the main passage, the same steps would be taken with regard to the latter, in order to make progress equal. Up to September 30 last, 5970 feet had been tunnelled on the north side and 3683 feet on the south side; total, 9653 feet.

The heading of the main tunnel is, at present, not more than about 6½ feet high and about 10 feet wide; nor is it the intention to increase these dimensions in the first instance. The full profile of the tunnel will, however, measure about 16 by 20 feet, and a strong rear-guard is constantly occupied in blasting the walls and roof to the required width and height. The lining with masonry will commence on a large scale as soon as the tunnel has advanced sufficiently to permit of this work being started at several places simultaneously.

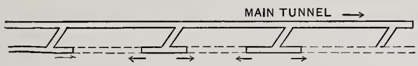


THE SIMPLON HOSPICE

THE TUNNEL COMPANY'S WORKS NEAR ISELLA

A PART OF THE HYDRAULIC PIPE LINE TO THE TUNNEL

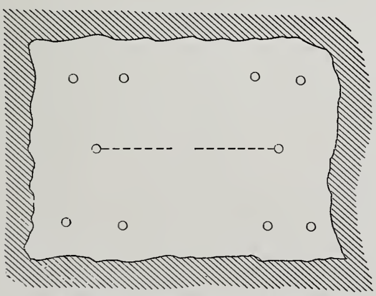
The system of drilling and blasting used in the heading presents no essentially new features. Its efficiency is apparently as near perfection as long experience can bring it, the position and



METHOD OF REGULATING THE RATE OF PROGRESS IN THE TWO TUNNELS

length of drill holes, blasting charges, etc., being adjusted to a nicety for getting the best results.

The boring machines are of the usual type, but certain working parts have been greatly improved by Mr. Brandt. They are worked by hydraulic power generated by three steam engines of, together, 300 H. P. and transmitted to the face of the heading by means of high-pressure pumps and pipes. Later on, the engines will be replaced by turbines. The necessary quantity of water is conveyed from the River Rhône in pipes of about 63 inches diameter and nearly two miles in length. At the south end the aqueduct is nearly three miles long. After having served its double purpose of working the boring machines and clearing away the débris after shot-



CROSS SECTION OF HEADING SHOWING LOCATION OF BOREHOLES

firing (about which more anon), the water runs to waste through the tunnel, where one has to wade in it, sometimes knee-deep.

The boring machines stand on rails so as to be easily withdrawn from the working face during blasting operations. Two or three holes, 6 feet deep and 4 inches in diameter, are bored simultaneously. Altogether, a series of ten bore-holes are bored and fired together. Each such series is called an "attaque." Eight holes are placed in pairs in the four corners of the working face and are bored straight ahead. The remaining two bore-holes are drilled obliquely so as to form a centre cut.

It takes from three to five hours to bore a series of ten holes, according to the hardness of the rock. When the holes have reached the required depth the boring machines are withdrawn to a safe distance and the holes are each charged with about 10 kilograms of blasting gelatine. The powder fuses are lighted and the workmen retire

CROSS SECTION OF FIRST HEADING

speedily to the shelter of the nearest cross-cut. Strange to say, no sound of the explosions is heard a thousand yards away from the working point, and yet the resulting air pressure at that distance is such as to cause pain in the ears.

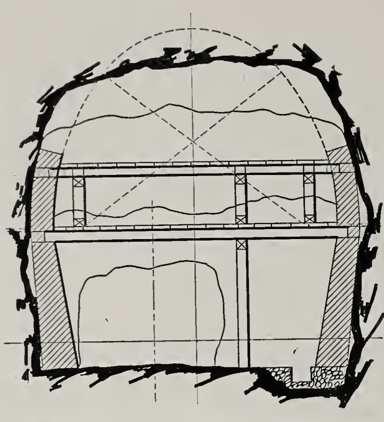
It is always with a peculiar sensation of anxious suspense that one waits for strong charges of explosives to detonate underground. The dark surroundings, the absolute silence,—for no one speaks during this waiting time, except in low whispers, — and the knowledge that when the silence will be at last broken it will be with the most uproarious contrast conceivable,—all this adds, perhaps, to the suspense of the moment. A visitor, especially if it be his first experience, is not likely to forget it.

But even the miner has his share of excitement. There are misfires to be dreaded, an occurrence which is always connected with danger and much loss of both time and labour. With reasonable care, and when the best materials are used, misfires are, fortunately, very

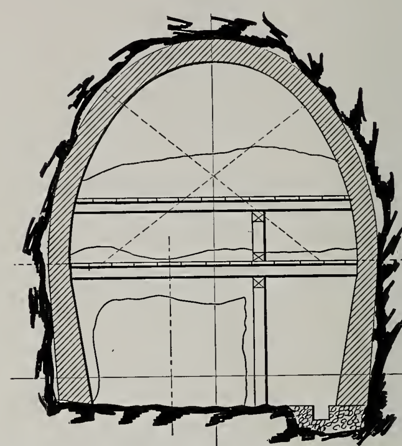
rare. Yet it is a relief when the last shot has been counted out and the signal thus given that the working face is ready for the next "attaque."

pressed air at a pressure of 100 atmospheres and fires a projectile of 900 gallons of water.

Once the cannon has been placed in



CROSS SECTION OF TUNNEL DURING CONSTRUCTION



SECTION OF THE TUNNEL AS IT WILL APPEAR WHEN COMPLETED

The somewhat tedious work of clearing away the débris will shortly be done in the Simplon tunnel with a minimum loss of time. To accomplish this the indefatigable Mr. Brandt has added an-

position the powder fuses will be abandoned and the shot-firing will be done by electricity. In this manner it will be possible to fire the explosive in the bore-holes and the gun simultaneously.

THE ITALIAN CUSTOM HOUSE AT ISELLA

other formidable weapon to his armoury of demolition, viz., a gigantic air-gun, 300 feet long, and with a calibre of 6½ inches. This gun is charged with com-

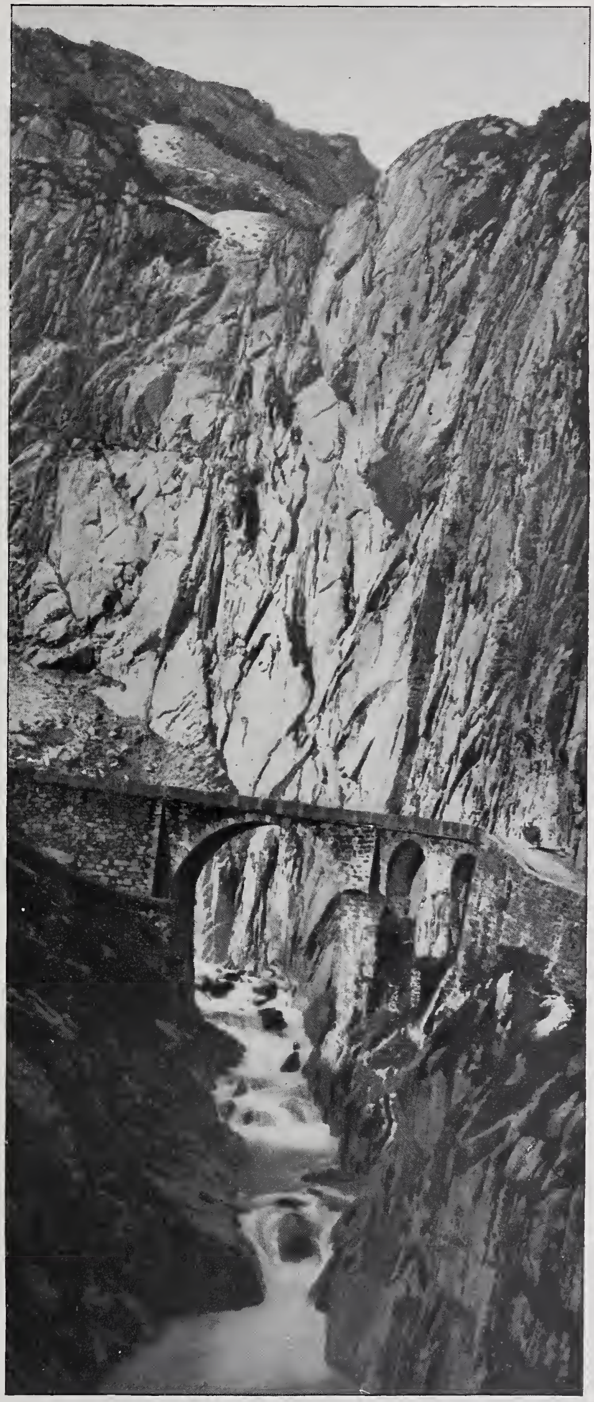
Thus, at the same moment as the solid rock is splintered into a heap of fragments by the blasting charges, a huge volume of water is hurled against the

débris, which is instantaneously washed right away from the working face and left against the wall some 50 yards further down the tunnel. Mr. Brandt has already had the opportunity of testing his hydro-pneumatic gun elsewhere, and has found it to answer its purpose perfectly.

Another ingenious device is the intended use of water for cooling purposes, and great hopes are entertained as to the beneficial results to be derived from it as soon as the tunnel advances towards the middle of the mountain, where high temperatures may be expected. It is intended to cool the air in the tunnel by means of fresh mountain water, which will be conveyed into the tunnel through pipes and discharged in the working places in a fine spray. In this manner it is expected to keep the temperature below 75 degrees Fahr.

According to the terms of Messrs. Brandt, Brandauer & Co.'s contract with the railway company, the former are to receive 70 million francs for the work. The tunnel must be completed by May 13, 1904, failing which the contractors become liable to pay a fine at the rate of £200 per day. On the other hand, they receive a bonus of £200 for each day saved.

At the present rate of progress, which is from 16 to 22 feet per 24 hours, and provided that no unforeseen difficulties of construction are met with, it may be taken that the work will be finished within the stipulated period, and as soon as the hydro-pneumatic gun can be



THE DEVIL'S BRIDGE ON THE SIMPLON ROUTE

ALONG THE SIMPLON ROUTE

brought into action, a gain of about 6½ feet per day will probably be made. But there appears to be yet one more chance of gaining time, and this lies in the proposed use of liquid air as an explosive.

The explosive now used is blasting gelatine,—the strongest known. It is manufactured at a Swiss dynamite factory specially erected in the neighbourhood of the tunnel workings. The consumption of explosives in the Simplon tunnels is about 50 kilos per running metre (about 33½ pounds per foot). This represents, roughly, £200,000. The tunnel company are bound by contract to buy all their nitro-glycerine explosives from the local factory, but have free hands as regards other explosives.

As previously mentioned, the bore-holes are at present 4 inches in diameter and 6 feet deep. With the specially constructed steel drills used in the boring machines the diameter may be increased to 15 centimetres (6¼ inches) without appreciably lengthening the time required for boring. The reason of the smaller holes being preferred is that blasting gelatine appears to have reached the highest degree of efficiency in cartridges of about 3½ inches in diameter, and to increase the latter would, therefore, mean waste of material. If an explosive could be found doing a maximum of work in cartridges of considerably larger diameter, and, at the same time, comparing favourably as to price, a very material advantage would be gained, for with the larger cartridges the depth of the holes could likewise be increased and each "attaque" would then measure about three metres instead of two, as at present.

Explosives made with liquid air seemed to be the very thing that was wanted. They left nothing to desire as to strength, and the price was comparatively low, as liquid air could be made on the spot, where ample water power is

available. But there were other difficulties which militated against the use of this new substance, though several of these have been overcome. For instance, it is now possible to keep liquid air in specially constructed vessels for fourteen days and longer.

Again, with cartridges of 6 inches diameter, the absorbed liquid air did not evaporate at such a rate as to render them useless a few moments after they had been taken out of their bath. Cartridges of this diameter would have a life of over a quarter of an hour, which would be sufficient for loading and firing. But one great drawback remains. It is the danger of premature explosion of the cartridges when accidentally brought into contact with fire, and as naked lights of the oldest type are used everywhere in the Simplon tunnel, such an accident would seem extremely probable.

A liquid air cartridge is made as follows:—A cylindrical paper or cardboard wrapper is filled with the powdered material intended to support combustion, the liquid air being, of course, the oxidising agent. The cartridge is then bodily immersed in liquid air. In from 15 to 20 minutes it is soaked through and is ready for use. Several mixtures of carbonaceous bodies have been tried as substances supporting the combustion, and it has been found that not all of them involve the same degree of danger. Some of the cartridges made as above described burn away more or less violently when ignited by flame, while others explode almost immediately. Unfortunately, the mixtures which have proved comparatively safe are also the least effective. It, therefore, remains to be seen whether a mixture will be found which combines sufficient explosive strength with safety of handling. Meanwhile, it may be said with a fair degree of certainty that liquid air mixtures will never be generally introduced as a blasting agent, for apart from the difficulty of preparing the cartridges under ordinary mining conditions, it is an exceptional thing to meet with 6¼-inch cartridges in ordinary mining (1 to 2 inches being the usual sizes), and a thinner cartridge does not retain the liquid air long enough to be relied upon for shot-firing purposes.

With the work in the Simplon tunnel it is, of course, a different matter. The conditions there are different. It is altogether an exceptional case, and if the experiments with liquid air should ultimately prove successful, the advantages achieved may mean the completion of the tunnel in 1903 or even earlier.

THE CHIEF ENGINEER'S RESIDENCE NEAR ISELLA

Professor Linde, of Munich, who has done so much to render the liquefaction of the atmospheric air an industrial success, personally conducts these experiments at his laboratory near Brig, and his thorough knowledge of the subject

THE TUNNEL ENTRANCE NEAR ISELLA, SHOWING THE HYDRAULIC PIPE LINE

promises a successful issue, if it is to be attained at all.

NOTE.—Since the above account was written news has come to hand that the manufacture of liquid air for blasting purposes has been abandoned, at least for the present, though it is not unlikely that more will yet be heard of this new explosive agent.—THE EDITOR.

A CENTURY'S PROGRESS OF THE STEAM ENGINE

By Dr. R. H. Thurston

TWENTY years ago, reviewing the progress of the steam-engine to date, and seeking the reasons of the steady gain observable in the economy of its operation, the writer, in his "History of the Growth of the Steam-Engine," remarked:—

"The direction of improvement has been marked by a continual increase of steam pressure, greater expansion, provision for obtaining dry steam, higher piston speed, careful protection against loss by radiation and conduction, and, in marine engines, by surface condensation."

This statement, and the extended discussion of the details of method and manner of steady improvement during the time since Watt, which were then and there given, apply as well to-day and require absolutely no qualification, and the summary holds good for the century. The salient points of this progress are three:—(1) increased steam-pressure; (2) proportional increase of the "total" ratio of expansion; (3) continual rise in speeds of piston and of rotation.

Of these methods, the first and second, which are, in fact, properly means of attaining a single object, the widening of the temperature range of the engine cycle, give increased thermodynamic efficiency, and the third produces lessened wastes of heat and work by permitting a larger amount of work to be done by a smaller machine. Roughly estimated, the gain by these methods is proportional to the increase of the square root of the total range of temperature worked through, and to that of the reciprocal of the time occupied by a stroke of piston or by a revolution of the engine, *i. e.*, to the increase of engine speed. It will be interesting and useful to note what have been the magnitudes of these quantities since, at the beginning of the century, the steam-engine assumed its modern form and commenced its great work of producing our modern civilisation. The following statements and the accompanying diagrams show, approximately, perhaps with considerable and sufficient accuracy, what have been the engine speeds, the expansion ratios and the steam pressures since the now expiring century was born, what have been the rates of advance, and what the amount of the gains effected.

The problem of the engineer engaged in the perfection of the steam-engine may perhaps be accurately and concisely stated thus:—

The conditions of the case as affecting the ideal, purely thermodynamic, machine, being known and exactly specified, to produce a real engine of similar cycle, free, to the greatest extent practicable, from the defects of cycle and from the extra thermodynamic wastes which characterise all real engines in higher or lower degree.

The ideal engine would be a purely thermodynamic machine, in the sense that its only wastes would be such as would occur in a steam cylinder constructed of a perfectly non-conducting material; it would not waste heat by conduction or radiation, or by transformation into useless work. The solution of the problem thus obviously involves simply the adjustment of a valve gear in such manner as to secure the

proper form of cycle, as a geometric figure, and the provision of either a non-conducting cylinder, of a non-conducting working fluid, or both, or, in case neither of these equivalents can be secured, such approximation to these ideal conditions through such other expedients as will insure the best possible approximation to the ideal. Superheating, compounding and the employment of high-speed engines are simply such expedients, while the increasing of steam pressures and ratios of expansion, and the adoption of condensation and of other plans for reduction of back-pressure, are expedients for increasing the ideal efficiency of the engine.

It will be interesting to look back over the century just closing and to observe to what extent the adoption of

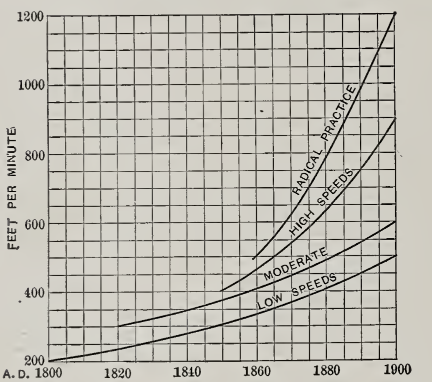


FIG. I.—MARINE ENGINE PISTON SPEEDS, 1800–1900

now familiar plans for improving the performance of the steam-engine during the period of its existence,—practically coincident in its working life with the nineteenth century,—have had the desired result, and how far efficiencies, duties and thermodynamic operations have been approximated to the figures for the ideal, thermodynamic, machine. The principal directions of general progress have been toward higher engine speed, toward higher steam pressures and correspondingly increased ratios of total expansion, decreased back-pressures, superheating and compounding, and the use of improved forms of valves and valve gearing.

Increasing engine speed secures greater immunity from losses by conduction and radiation, within and without, by simply securing a larger amount of work and the use of more steam in the unit of time with a given cylinder volume, thus reducing the waste per unit of weight of steam and of useful work to a lower magnitude. Doubling the speed of engine approximately reduces the waste percentages in proportion to the difference in the squares of the two speeds, while it gives, other things being equal, double the power, thus, also, reducing costs of construction for stated powers of engine. In the engines of Watt, the steam pumping-engine, or the Cornish engine as it came to be called, was more economical than the same size of rotative engine of the same builder because of the fact that, having no fly-wheel to steady its speed during the piston stroke, it took steam in such a manner as to cause the piston to start with a jump and to traverse the cylinder so rapidly as to give comparatively little time for waste by the condensation of the steam upon the cool surfaces of the metallic walls. It maintained its superiority in this respect until other forms of engine approximated a piston speed approaching that of the older machine, or were provided with arrangements for attaining the same result in reduced wastes by other means.

Modern engines, other things being equal, improve in efficiency and give increased duty as they increase in speed. Fig. 1 shows what has been the extent and rate of progress in this direction in the case of the marine engine, taken as an example of a type, since the beginning of its work and to date. This means, practically, during the nineteenth century, since the work, at earlier dates, of Fitch and other inventors brought forth no practical results.

John Stevens, in 1804, and Robert Fulton, in 1807, were the pioneers in practical employment of the steam-engine in marine work, though it should not be forgotten that John Fitch, in the United States, actually transported passengers for a regular fee on a regularly settled route, employing several steamers of small size and very moderate

speed, between Philadelphia and Bordentown and Trenton, on the Delaware River, several years earlier, between 1787 and 1791.

In the figure, the lowest curve on the diagram represents the progress made in the conservative practice of Watt and his successors and their imitators; the next higher curve shows the advances effected by rivals and more radical constructors from the year 1820 onward; the next in order shows the higher speeds, considered, when Corliss and his contemporaries introduced them, as dangerously high; while the upper curve exhibits the limit of radical practice, the danger-line as it was thought, of the last forty years of the century. Thus it is seen that piston speeds have risen from 200 to 500 feet per minute, in marine practice of a conservative kind, during the nineteenth century; that what may be to-day called moderate practice has advanced from 300 to 600 feet per minute; while high speeds for their dates have increased from 400 feet at about the middle of the century to 900 feet at its close, and, in radical practice, from 500 to 1200 feet. In exceptional instances, or in the effort to accomplish a special *tour de force*, speeds of considerably greater magnitude have been, for a time, maintained. The figures here given, however, represent settled practice in the business of certain builders, or in certain classes of constructions. Thus, torpedo-boat builders adopt the radical practice, while constructors of small and short-route craft keep speeds down to what they regard as economical and permanently safe rates.

Speeds of engine may be measured either by speeds of piston, as above, or by speeds of rotation, and it is obvious that the latter and the length of stroke of engine piston together determine the speed of the piston. With some engines, as those with detachable valve-gear, the speed of rotation is limited to that at which disengagement of the valve may be positively assured; and this, with, for example, the Corliss engine, is, at present, not far from 100 revolutions per minute, although instances of much higher speeds are known, and, in one case at least, a speed of 160 revolutions per minute was maintained for years together.

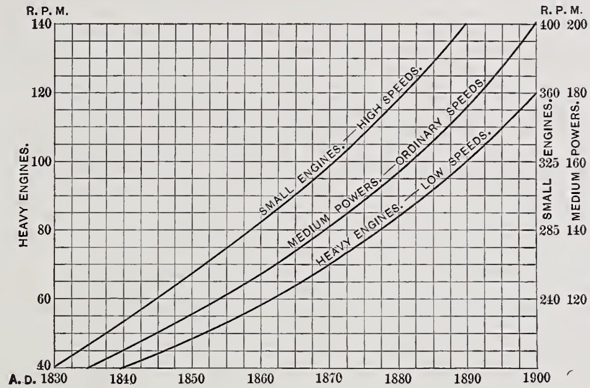


FIG. 2.—SPEEDS OF REVOLUTION (MARINE) 1800-1900

The method of progress of rotative speeds is shown in Fig. 2, and, naturally, follows closely the direction observed in the preceding case. Here the lowest curve in the diagram is that for heavy engines and a very conservative practice; the intermediate line gives the speeds for common good practice at the respective dates; and the higher curve shows the limit of what is considered safe, and a radical practice, where, as in practically all marine engines, no limit to speed of rotation is set, as in so many stationary engines, by the character of the system of steam distribution. Each curve has been given its appropriate scale, and the latter is suitably designated on the margin of the diagram.

Torpedo-boat practice illustrates the highest case and the work of the average good marine engine-builder the middle case. The lowest line has risen from 40 revolutions, in 1840, to about 100 or 110, in 1890 to 1899, and promises to become, in the best moderate practice, 120 revolutions at the end of the century. The very largest marine engines,

with their diameters ranging up to three and four feet in their high-pressure cylinders, and, in low-pressure cylinders, six and eight feet, and with their stroke of five or six feet, are now driven up to 90 and 100 revolutions per minute with apparent safety, and unquestionably gain in economy and in reduced weight and volume. Medium powers and sizes have similarly ranged from 100 to 200 revolutions, and " positive motion valve gears " and the small high-speed engines of torpedo-boats have carried radical practice in recent years up to speeds of rotation formerly incredible, now ranging all the way from 400 to 600 revolutions. The steam-turbine, meantime, has set a pace which even the most radical torpedo-boat constructors can never hope even to approach with small engines,—5000 to 10,000 revolutions per minute,—their largest sizes probably seldom falling much below a speed of 1000 to 2000 revolutions.

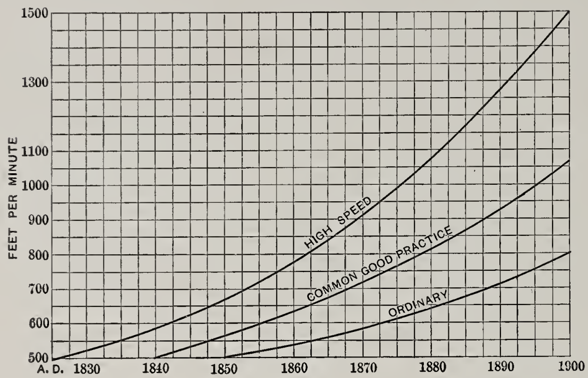


FIG. 3.—PISTON SPEEDS OF LOCOMOTIVES

Fig. 3 exhibits the speeds of piston of the locomotive from the earlier days of its introduction to the present time, in this case, also, the progress, practically, of the century. The lower line represents what seems to have been considered standard practice from the time when there was such a practice; the middle line shows the advances of the century in good common practice, and the upper line is that illustrating a high-speed practice. These deductions, however, are not to be taken as either exact or controlling. The speed of the locomotive is necessarily very variable, the character of its service varies greatly, and builders are controlled by these varying conditions far more than by any considerations of fuel-saving.

Ordinary practice became established about 1850, after nearly a half-century of experimentation and of variation of type and method of construction. The standard was set up, it may be fairly asserted, by George and Robert Stephenson about 1830. There is, however, far less variation in the practice of reputable builders in this department of steam-engine construction than in marine practice. It should also be stated that, in those earlier days, there were occasions on which the engines of the time were forced up to a speed which rivalled that of similarly operated engines of our own day, as when George and Robert Stephenson, in September, 1830, pushed the *Rocket* up to 36 miles an hour, carrying the wounded statesman Huskisson to his home, 15 miles in 25 minutes. That engine was, in 1837, driven up to a speed of 4 miles in 4½ minutes on the Midgeholme Railway, near Carlisle, a speed of nearly 55 miles an hour.

Common practice, during the last half-century or more, has ranged from the figures of Stephenson and his followers, as above, from 500 or 600 feet per minute piston speed, to about 1000 at the close of the century; while radically high speeds may be taken as about 30 or even 50 per cent. higher in cases of maximum speeds on special occasions.

Steam pressures have been constantly rising since the time of Watt, although, curiously enough, some of the experimental work of the inventors of the marine engine, as well as those of the locomotive, has been done with pressures of considerable magnitude, while the stationary engines of Jacob Perkins were operated at pressures of from 1000

to 1500 pounds per square inch, and that inventor, about 1836, proposed pressures of 2000 pounds. Dr. Albans, a little later, also adopted pressures of 600 to 800 pounds and worked small engines with, for a time, great economy and without any apparent difficulty. Standard marine practice, however, like the steam pumping engine practice of the early part of the century, involved the employment of steam of little more than atmospheric pressure and permitted but very tardy increase for many years.

Fig. 4 exhibits the general trend of this change, at sea, from the early part of the century, in vessels operated on regular routes. For a long time the rise was extremely slow; but at about the middle of the century the introduction of the surface condenser, by permitting the use of fresh water in the boilers, or at least the avoidance of the introduction of sea-water, and by thus enabling the engineer to evade the difficulties arising from constant precipation of solid matter on the heating surfaces of the boiler, caused the adoption of steadily increasing steam pressures and allowed the designer to provide for the utilisation of the wider range of working temperatures which accompanied and gave reason for rise of pressure and larger thermodynamic efficiencies.

From that time, the rise has been increasingly rapid, and the law of increase with time is shown with a fair approximation to the mean by the curve of the diagram. The increased pressure, in turn, made it necessary to adopt, first the compound, the double-cylinder, engine; then the triple; and finally the quadruple-expansion machine. The compound came in about 1854, the triple in 1874, and the quadruple during the closing years of the century. The demand for increased pressures, also, compelled a gradual modification of the standard constructions of steam-boiler and finally forced the adoption of the now familiar water-tube boiler with its externally heated surfaces, — a form of boiler original with the earliest inventors of the steam-engine of modern type.

The increase in the ratio of expansion adopted, from the first, has been, in a manner fairly constant in its relation to the pressure, and may be roughly taken as, for common practice in condensing engines, the "absolute" steam pressure at the boiler divided by ten pounds. The terminal pressure, in good practice, has been about 10 pounds, falling, in the engines of highest efficiency and giving maximum duty for their time, to 8 and occasionally to 7 or even 6 pounds, absolute. The precise relation of the ratio of steam pressure to back-pressure to the ratio of "total" expansion in all classes of engine has necessarily been affected very appreciably by the degree of approximation secured to truly ideal, thermodynamic, adiabatic expansion. Initial condensation and, later, re-evaporation, have a marked effect upon this relation, and this, in turn, is determined in amount by the character of the construction and the "quality" of the working fluid.

The final improvement of the steam-engine, marking the best practice of the

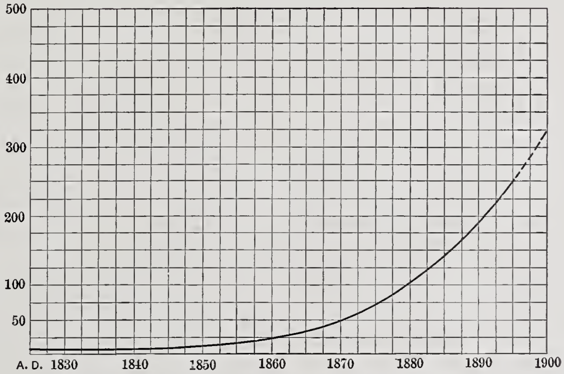


FIG. 4.—STEAM PRESSURES IN MARINE ENGINES

century, and particularly of its later years, is that which reduces that variation from the thermodynamic ideal which is consequent upon internal waste due to exchange of heat between the steam and the metal of the working cylinder. Rankine's ideal "cycle of the

non-conducting cylinder" can be secured either by actually making the cylinder non-conducting or by giving the steam so nearly gaseous a quality as to reduce appreciably, if not entirely, this heat-exchange. Either fluid or cylinder-wall being non-conducting, heat-exchange is impossible.

Steam drying and superheating has come to be recognised as an essential process in the economical operation of the steam-engine. Separators at or near the engine cylinder are now made very efficient in the removal of all particles of water from the steam entering the engine, and thus superheating is very effectively facilitated; but superheating itself is a problem in construction and in operation which is not even yet completely solved. Nevertheless, all engines exhibiting maximum economy, to-day, employ steam effectively dried and more or less superheated. These processes are not only practised in the passage of the steam into the engine, but they are also often employed between cylinders where the engine is of the multiple-cylinder type. Here separation is always practicable and easily made effective; but superheating, even where it is provided for, is seldom accomplished in "reheaters." One heat-unit employed in superheating the steam, preliminarily to its introduction into the cylinder,—whether high-pressure, intermediate or low,—is worth several employed in evaporating additional steam; yet such are the practical difficulties that even the best of modern engines are rarely supplied with steam superheated more than fifty degrees F., and effective superheating between cylinders is very seldom accomplished. Where it is successfully introduced, the effect is probably always to very considerably improve the action of the machine and reduce its expenditure of steam and of fuel. The highest modern records are held by engines in which the ideal thermodynamic conditions are most closely approximated in this respect. The usual variation of efficiency with variation of engine speed is not, in this case, so observable, and is far less important.

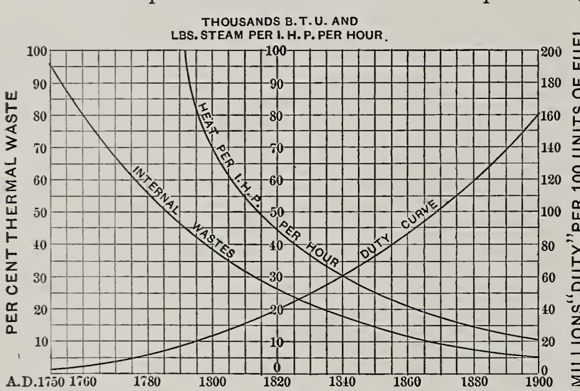


FIG. 5.—PROGRESS OF STEAM ENGINE EFFICIENCY, 1750–1900

The fundamental deductions from experience, as well as from scientific examination of the case, and the principles controlling the construction and operation of the steam-engine in which high efficiency is sought, are the following:—

(1) Make the steam pressure adopted as high as, under existing conditions, is safe.

(2) Adopt the lowest practicable back-pressure.

(3) Expand through the widest range of temperature and pressure found commercially satisfactory.

(4) Adopt as high engine speed as is safe.

(5) Employ dry, and, if practicable, moderately superheated, steam in all cylinders.

(6) So design the machine that friction and external wastes of heat shall be reduced to the lowest practicable amounts.

(7) In the application of any expedient for promoting efficiency, seek that limit at which further gain is compensated by the additional costs of its production. In choosing an engine type for any application, seek that which returns in useful power the largest amount of value for each unit expended in its procurement.

Progress in the improvement of the steam-engine is measured by the gain

in " duty " secured by improvement in its construction and operation. This gain is exhibited in Fig. 5, in which are presented the curves of mean efficiency of the steam-engine of the best types from the time of Smeaton and the Newcomen engine to the end of the nineteenth century.

A duty-curve measures the gain in amount of useful work performed by the unit of fuel consumed; the curve of heat and steam and fuel consumption exhibits the quantity consumed per horse-power and per hour. It may be also noted that the internal wastes of the engine, at first constituting 95 per cent. of all the heat and steam and fuel supplied, have become extinguished to such an extent that 80 per cent. or more of the steam has become available for use in the engine cylinder.

The curve of heat, steam and fuel consumption is, perhaps, the most familiar measure of the growth of the engine efficiency during the century just elapsing. The scale is one of thousands of British thermal units per indicated horse-power per hour and of pounds of steam for similar units, it being assumed that each pound stores 1000 heat-units between feed-water and steam temperatures. It is also a scale of tenths of a pound per horse-power per hour, assuming the most efficient of steam boilers,—with an evaporation of ten pounds of steam per pound of fuel,—to be employed. It will be seen that the gain has recently approximated 20,000,000 foot-pounds per 100 pounds of fuel on the duty-scale, one pound of steam and one-tenth pound of fuel, per decade, on the scale of heat expenditure, and that the decrease in magnitude of internal wastes has been, and is at present, about 1 per cent. per decade. These rates of gain may be taken as those of our own time, and slightly lesser gains, with a progressively decreasing rate of gain, are likely to continue for the immediate future, precisely as the rates of increase of steam pressure, of expansion ratios and of engine speeds may be expected to extend the curves, through the next decade or more, along the same directions as hitherto observable in the diagrams, provided no unexpected change, due to invention or the approach of the curve to an, as yet unknown, critical point, shall compel a change in the law of progress. No such change affecting our prophecy, we have a safe, a scientific and an instructive and availably useful prediction. " Science here reads an oracle."

The limit for the immediate future would seem to be about ten pounds of steam, one pound of fuel, and something inside 200,000,000 foot-pounds duty, beyond which figure it would be rash to expect further progress, except under conditions still beyond the view of the engineer of this time.

Individual engines have excelled in efficiency the records here indicated as the best general results of the progressive improvement of the century. It may prove interesting to gauge both the approximation of the averages already presented and of the individual machine to the ideally perfect steam-engine. Were it practicable to produce an absolutely perfect thermodynamic machine, whether steam-engine or any other form of heat-engine, and whether operated with gas, vapour, liquid or even solid working substance, its maximum efficiency would not be unity, but that fraction which is measured by the ratio of the working range of temperature to the absolute temperature of its maximum limit, the Carnot efficiency. This is, therefore, what must be accepted as the standard with which to compare any given case. Numerically it is a variable quantity, obviously increasing with the elevation of the steam pressure in the case of the steam-engine. It is known to be proportional, very closely to the logarithm of that pressure where the back-pressure is a practical minimum. Its value is sufficiently accurately given, for present purposes, by the expression measuring costs in steam, heat and fuel,

$$Q = a \div \log p',$$

in which, for heat-units per H. P. per hour, a may be assumed to be about 15,000; for steam in pounds per H. P. per hour, a may be taken at 15; and for fuel, take a at 1.5. For the measure of efficiency, unity as the stand-

ard, we will employ the expression,

$$E = 12.5 \log p'$$

which will serve within the customary range of steam pressures.

Employing these several expressions, it is seen that the efficiency of the Carnot engine, under the usual conditions of pressure-range, may be taken at 25 per cent. for 100 pounds steam pressure, and that the rise of the pressure to 1000 pounds would give approximately 37.5 per cent. efficiency. Meantime, the expenditure in heat-units would be 7500 per H. P. per hour; that of steam, at 1000 units per pound, would be 7.5; and that of fuel about 0.75 pound, at the lower pressure; while, at the higher, these figures would become 5000 B. T. U., 5 pounds of steam, and 0.5 pound of good fuel, burned in a boiler of high efficiency.

The Rankine cycle, defective in its lack of that compression which is an essential characteristic of the Carnot cycle, gives constants in our equations about 20 per cent. above those of the latter, measuring heat, steam and fuel consumption, and proportionally lower in measures of efficiency. Where heat-wastes occur, as in the real case, to the extent of 20 per cent. or more, these variations from the ideal case become proportionately increased. The expenditures of the best engines will average, in this case, probably 20 per cent. internal waste and the constants become about 18,000 and 22,000 for the ideal and the real case, respectively, as measuring heat expenditure, and 15 and 18 for the constant in the measure of efficiency.

Fig. 6 shows, on this basis, the ideal limit of the Carnot cycle, measuring efficiency by expenditure of heat in thousands B. T. U., costs in steam and in fuel being computed on the assumption of one thousand B. T. U. per pound, and ten pounds evaporation per pound of best fuel, in the best steam boilers.

The scale and diagrams are constructed for a pressure limit of 500 pounds per square inch.

The curve at the left of this diagram represents the ideal case of Carnot and its increasing efficiency as the pressure employed rises from the low figures of the middle of the century and earlier, to the maximum for the advanced practice of leading engineers of to-day. The costs of the horse-power range from between twelve and thirteen pounds of steam per hour, at the minimum pressure, to approximately nine pounds at 100 pounds pressure, eight and seven respectively, at 200 and 300 pounds pressure, respectively, and about six and two-thirds at 500. With 1000 pounds boiler pressure the figure should drop to about six pounds of steam per H. P. per hour.

It seems entirely practicable, so far as experience to date goes, to secure quite as close an approximation to the ideal case in the real engine at high as at low pressures. A waste of from 25 to 50 per cent. may be taken as a common range of efficiency loss in steam-engines by reputable builders, multiple-cylinder engines being employed for all pressures exceeding a hundred pounds boiler pressure, and the steam-jacket and moderate superheating being adopted for the most efficient machine, especially when, as is usual with pumping engines, having a low piston speed. Curves are inscribed on the diagram with these amounts of waste, and the area bounded by them may be taken as that occupied by modern good practice up to the present limit of good and common practice. The facts that the trend of existing and earlier practice so closely follows these lines and that the only experiments scientifically conducted and recorded to date for the maximum limit show the accuracy of the preceding conclusion, give us good basis for these general deductions.

The weight of steam per I. H. P. per hour is here given as $W = 18 \div \log p$ for the ideal case, while experience gives about $W = 25 \div \log p$ for good practice up to the highest limits yet accepted as standard. On the diagram, Fig. 6, are inscribed, also, the dates at which the noted efficiencies were attained by good builders generally and the approximate record for the close of the century. It will be

found that these chronological observations fall into a fairly smooth curve, and the deduction is as inevitable that not only will steam pressures and expansion ratios continue to increase in the immediate future, but also that improvement may be expected to continue in this direction, slowly with respect to rising efficiencies, rapidly in increasing pressures, as improved forms of steam boilers make it safe to employ such pressures, and as users and builders gradually yield their long-existing prejudices against high pressures.

We may expect a very few years more to see steam pressures for engines of high efficiency range from 500 to 1000 pounds per square inch, the quality of the steam being maintained at a high fraction by preliminary superheating on at least a moderate scale, with reheater superheating between cylinders in series, and with jackets on heads of low-speed pumping engines, as now practised. At the rate at which "safety boilers" are being improved and introduced at the close of the century, we may confidently anticipate that standard pressures will rise very rapidly until this revolution in boiler construction is completely effected. The twentieth century opens with the record for costs of power reduced to ten pounds of steam, nearly, per horse-power per hour, and the next century will undoubtedly see the approximation to the ideal case made much closer, while the ideal costs will be as certainly reduced from 10,000 B. T. U. per hour, nearly, to decidedly lower figures.

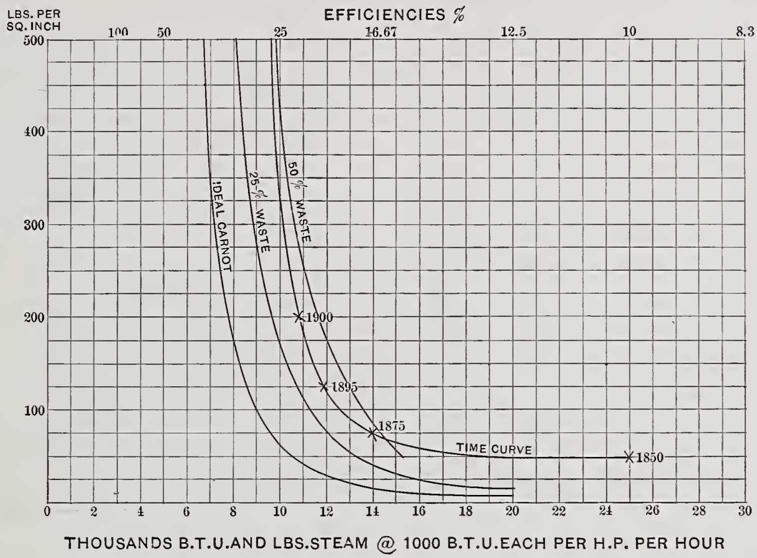


FIG. 6.—GAIN IN EFFICIENCY

Gain must, however, be expected to be comparatively slow in the coming century, both because of the fact that the great wastes of the beginning of the nineteenth century have already been largely reduced, leaving comparatively little opportunity to effect improvement in that respect, and also because, under any circumstances, the progress of improvement must always be at a constantly decreasing rate. If the coming century sees the costs of the indicated horse-power reduced to as little as 8000 B. T. U. per hour, or to eight pounds of steam, or to three-quarters of a pound of the best fuel, burned in the best boilers, it will be probably quite as great an advance as can fairly be anticipated for the first century of the next millenium.

SOME AMERICAN BRIDGE SHOP METHODS

By Charles Evan Fowler, M. Am. Soc. C. E.

AMERICAN competition in the engineering industries of the world has probably in no field attracted more widespread attention than in that of bridge building, due principally to the award to an American firm, last year, of the much-talked-of contract for the Atbara bridge, in the Soudan, which, in the ordinary course of events, should seemingly have gone to British builders. Why it did not go to them has, in the past half year or so, been made the subject of lengthy newspaper articles more or less to the point, though the reason which seemed to best explain the matter was that the price named by the American firm was the lowest, and particularly because the date promised for completion was the earliest.

Back of this must be sought explanatory details which are found, in part at least, in what are generally acknowledged progressive American shop methods, in the extensive use of labour-saving devices of all kinds, in the standardisation of every possible portion of the work, and it was the exposition of some of these features that was aimed at in the preparation of the following notes, which briefly outline the general layout and the regular course of work in any one of the leading bridge-building establishments of the United States.

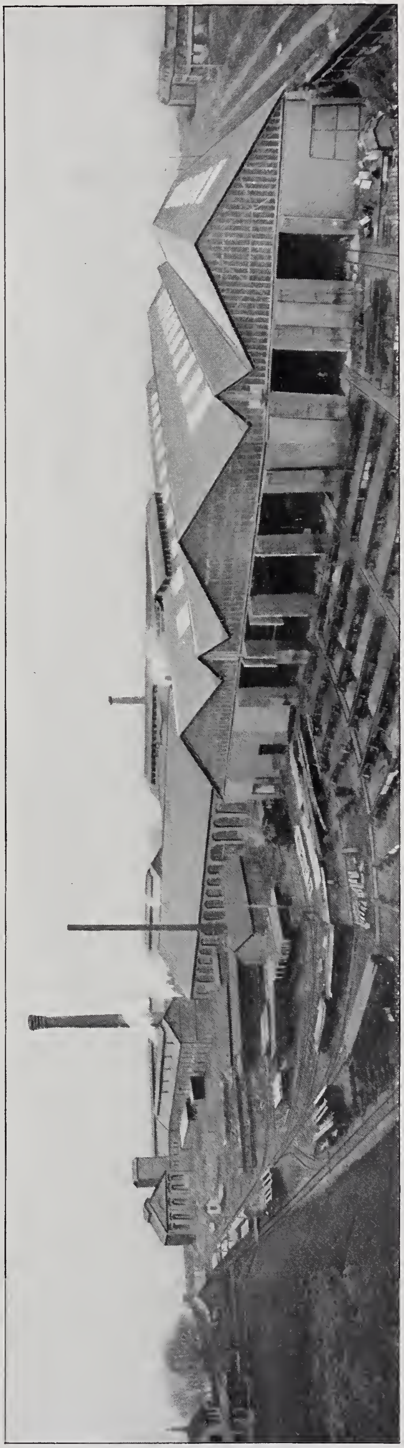
THE TEMPLET SHOP OF THE BERLIN IRON BRIDGE COMPANY, EAST BERLIN, CONN., SHOWING LAYING OUT IN PROGRESS ON THE FLOOR

American bridge shops of the best type may to-day be said to have reached as high a state of perfection as any other class of manufactories. As a primary condition for a low cost for shopwork, the newer shops are built with brick or tile walls, with a steel frame extending to the foundations, and with the tile or brick built in between the steel columns. Those portions which are in constant use by the workmen generally have a cement pavement. Heat is supplied in winter in most shops by steam, in some cases in direct steam radiators, but more frequently and most economically by the use of exhaust steam in coils of pipe placed in a heat chamber through which the air is blown by a large steam-driven fan and delivered by galvanised iron ducts to the various parts of the shop.

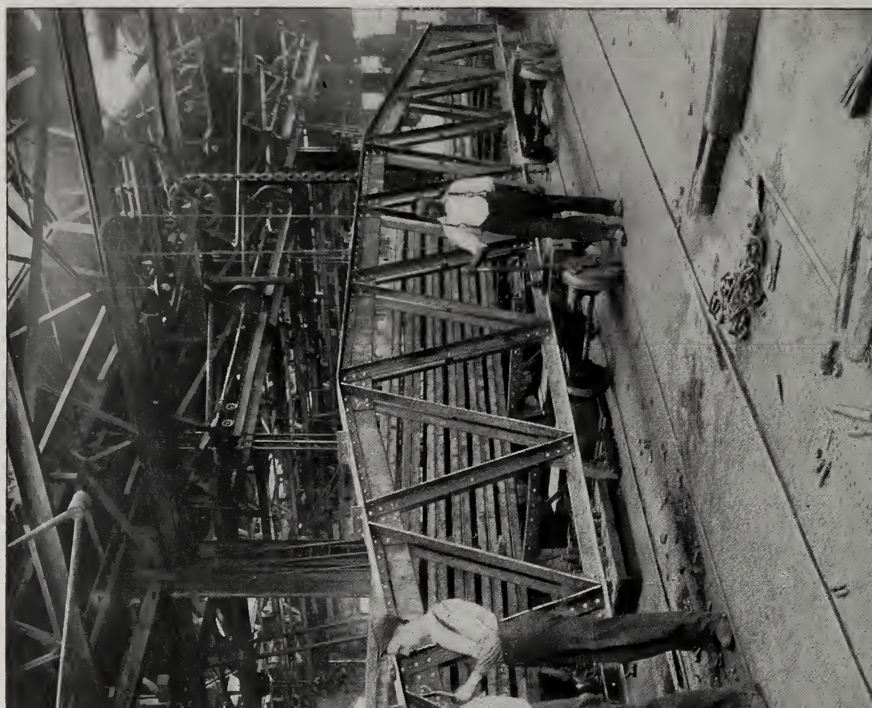
Plenty of light is provided by means of very large windows in the sides and ends, and large skylights in the roof. Some shops, in fact, have gone to the extreme of making the sides entirely of glass. Ventilation is provided for by movable sashes in the windows and by having either a continuous ventilator on the roof or plenty of large circular ones.

The various departments of a bridge works are usually housed separately, the boiler and engine house for the power plant comprising one part, the templet shop where the patterns are made another, and the riveting shop, where the material is laid out, punched, assembled, riveted up and finished; the machine shop, where the pins are turned, plates planed, and small tools and the like finished up; and the forge shops, where eye bars, loop bars, and other forgings are made, being similarly detached structures.

The riveting shop is the principal part of a plant and consequently receives the greater share of attention in arrangement and design. In point of general design, American riveting shops can be roughly divided into three clasess,—the straightaway type for those of moderate capacity, while the larger ones are of the parallel type, either double or multiple. The straightaway shop is a long and comparatively narrow building, into



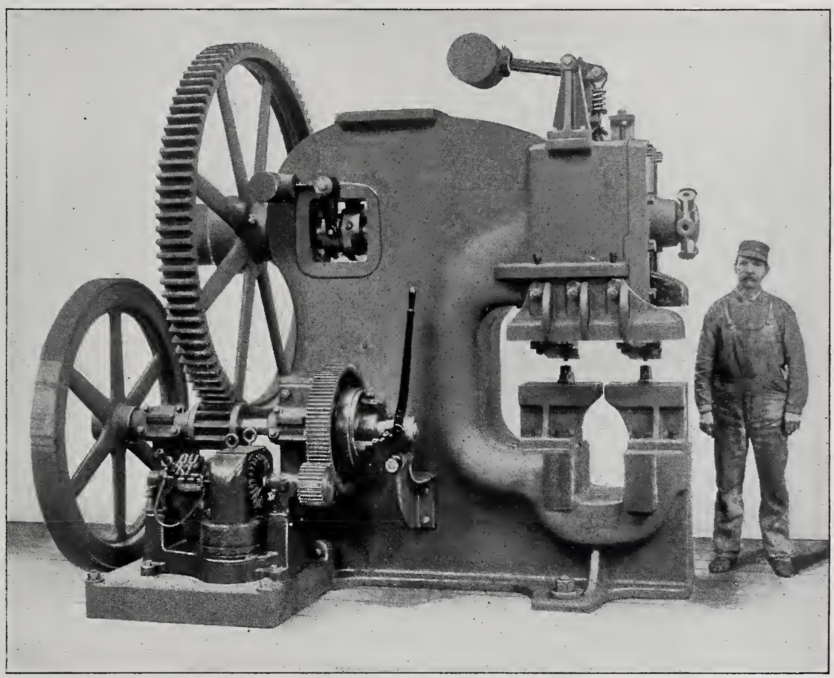
A PARALLEL TYPE OF SHOP. THE EDGE MOOR BRIDGE WORKS, WILMINGTON, DELAWARE



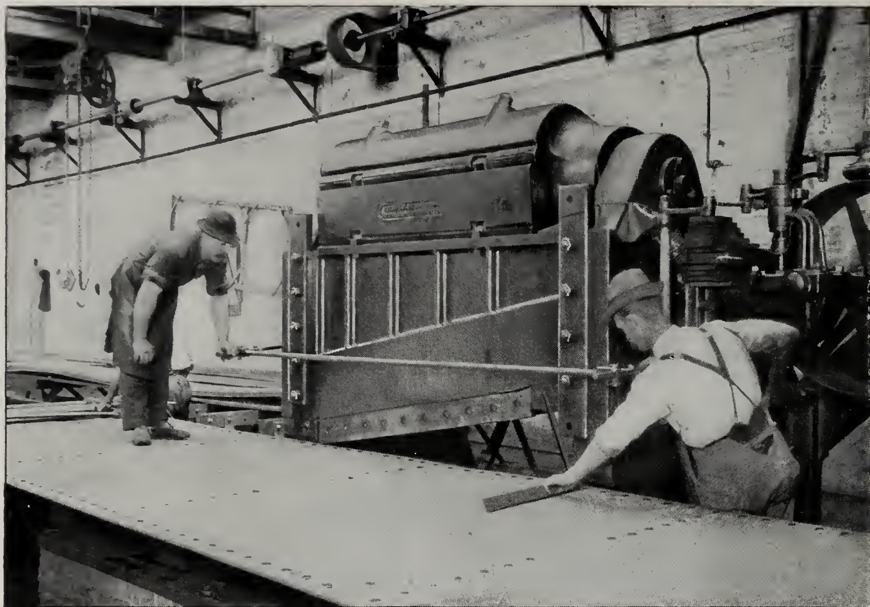
RIVETING UP A TRUSS IN THE SHOPS OF THE EDGE MOOR BRIDGE WORKS

which the raw material is delivered at one end and progresses lengthwise of the shop as the different steps in the process of manufacture are completed, there being a minimum of transverse travel. In the parallel type there is more of transverse travel, unless, as is the case in some double shops, there is duplicate machinery on the two sides, thus making in effect two straightaway shops. Where there are several parallel shops, thus making an approximately square or very wide shop, the material must travel crosswise over piles of material and machinery more than is economical.

When the contract for a bridge is received at the shop, the first step naturally is the filling out of a blank form with all the principal data, the date of completion, shipping directions, kind of paint to be used for shop and field, names of inspectors and the like, and this, together with the general plans, stress sheets, specifications and salient clauses of he contract, is transmitted to the engineering department. Pencil drawings are then made in sufficient detail, so that complete bills of material may be made up for use in ordering. Where the need for haste is urgent the orders are placed with the mills, subject to change when the drawings are approved, these being rushed to completion. This enables the booking of the orders for attention on the days when the rolls are in for particular sizes of shapes. Where the mill is an independent one, the bridge company has a representative on the ground continuously to see that the orders are not sidetracked in favour of later ones, and that material is shipped as quickly as it is rolled. Some specifications require the oiling or painting of the steel as soon as it is rolled, or at least as soon as it is received at the shops; but this is generally omitted to allow as much as possible of the scale to work off during manufacture before the paint is applied, and it seems likely that, unless some process is adopted for re-



AN ELECTRICALLY DRIVEN HEAVY DOUBLE PUNCHING MACHINE FOR I-BEAMS AND CHANNELS. BUILT BY THE HILLES & JONES COMPANY, WILMIMGTON, DELAWARE



SHEARING PLATES AT THE EDGE MOOR BRIDGE WORKS

moving the scale, the lead taken by some British railways, in erecting the work unpainted to allow the scale to rust off, will be generally followed. The bridges can then be cleaned with wire brushes and painted thoroughly.

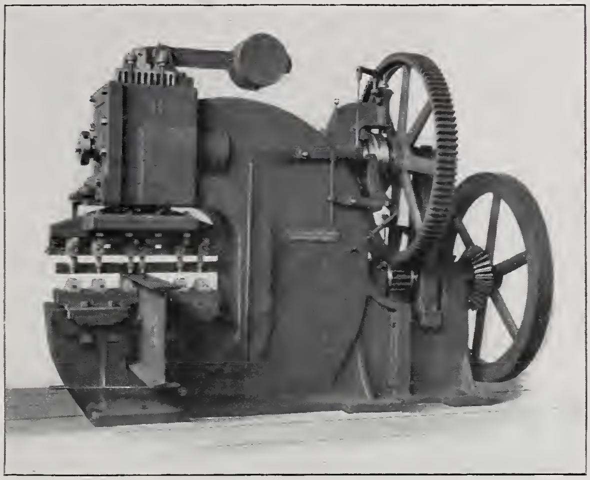
The preparation of the plans is the first systematic step in the process of construction, as the sheets of drawings are all of a standard size, 24 inches by 36 inches, and the order bills and shop bills are also on standard forms. The drawings are dimensioned and titled after a system, and the signs used to indicate countersunk or flattened rivets are such as to be readily understood in any shop in the country. The details are made in conformity with standard tables, the pins being of such diameters that the cutters used in boring pin holes will give a clearance of one-fiftieth of an inch; eye bar heads are made of fixed diameters for the different sized pins; upset ends and turnbuckles on adjustable bars are of standard sizes; the rivet spacing and gauging is taken from standard tables,—every detail, in fact, no matter how small or unimportant, is according to recognised standards. When the plans on tracing cloth have been approved by the engineer acting for the purchaser, blue print copies of them and of the shop bills are furnished the purchaser, the inspectors for the purchaser, and to the shops, each department receiving copies of all the plans and bills which call for work to be done by it. The templet shop prepares templets or punching patterns for each piece which goes to make up the riveted parts of a bridge. These templets are made of ⅞-inch pine boards or strips, which are sawed to exact width by a circular saw, then the gauge lines or pitch lines of the rivets are marked upon them, the rivet spacing is measured off upon these lines by the use of standard steel tapes, the pin holes or centres are located, and the ends are sawed to required lengths and bevels. With a power boring machine ⅝-inch holes are bored in the templet where each rivet hole is to be punched in the steel, and the pattern is then carried to the laying out department.

The cars containing the steel from the mill are switched onto a track under cover of the riveting shop, where elec-

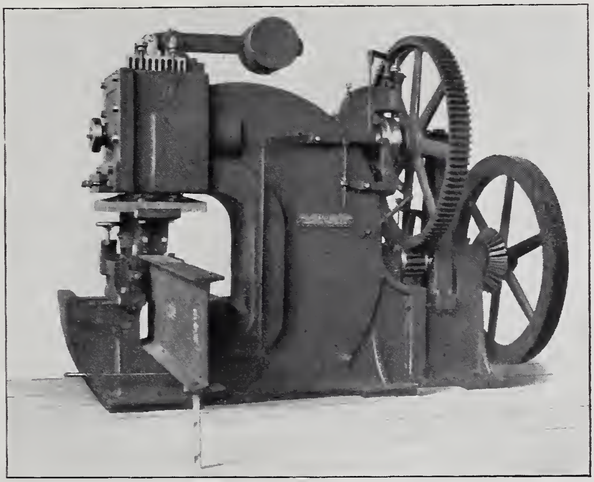
tric hoists of from a few to ten tons capacity are used in unloading, sorting and piling the material upon the skids ready for laying out, and all under cover, as the larger shops are prepared to keep material from the weather if it is desired by the purchaser. The electric hoists represent a great advance upon the old way of handling material by hand hoists, customary a few years ago, and the saving effected in time and labour is considerable, this item formerly representing as much as 5 per cent. of the total cost of manufacture.

While some of the mills are prepared to supply material which has been straightened, it is usually necessary to run the angles and plates through straightening machines, which are provided with four or five upper rolls and three or four lower rolls, respectively, between which the material passes. A machine for straightening wide plates, with rolls nine or ten feet long, is preferably driven by an electric motor geared directly to it. Where short bends are to be removed from shapes and bars or where material is to be curved for ornamental brackets, drawbridge drums and other similar purposes, a machine is employed which operates similar to a rail bender.

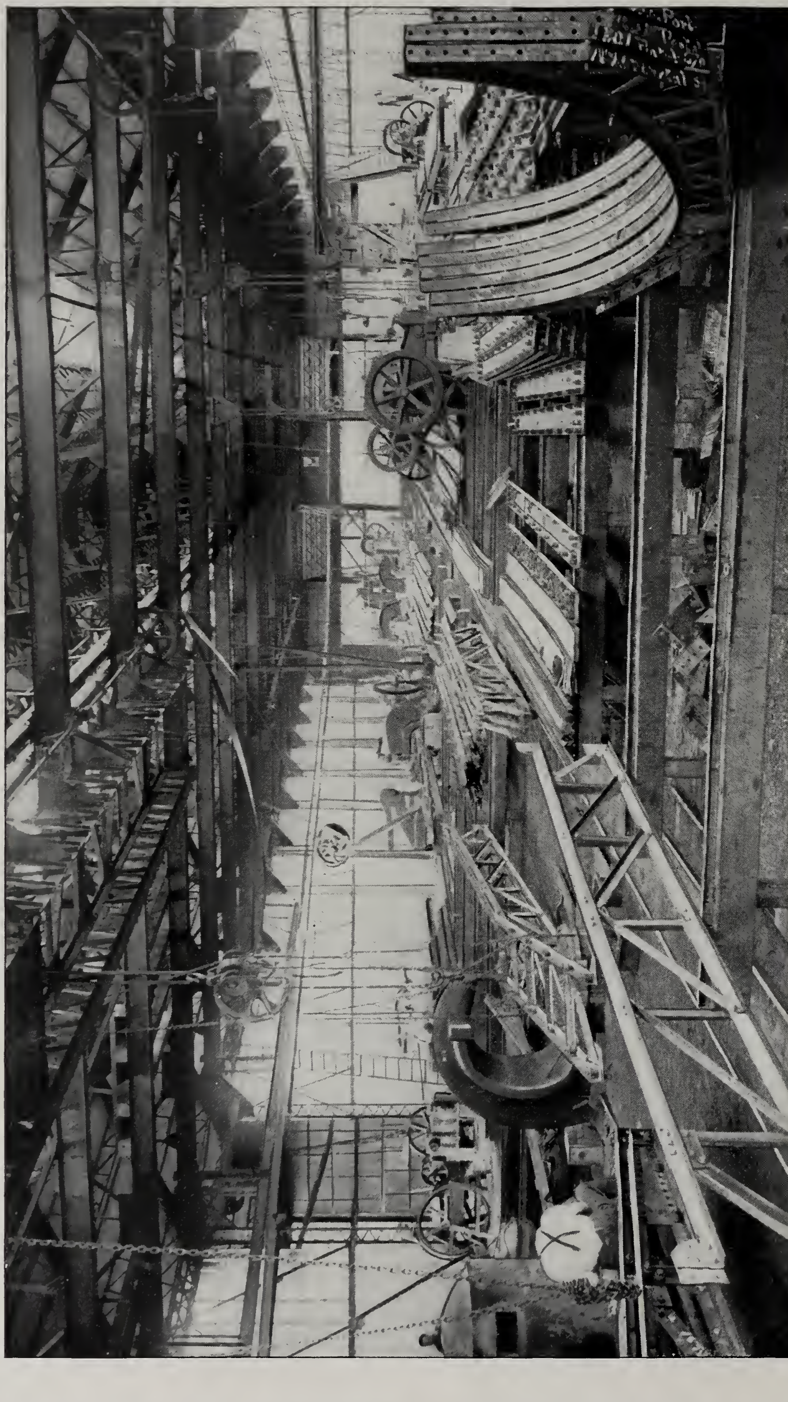
When the bends and buckles are all removed, the various templets are clamped, in turn, to the plates or shapes by the layers-out, who, with centre punches fitting the holes and hand hammers, make punch marks where the holes are to be located, and also mark the pin holes and cut-offs. Heavy channels and beams are cut off by cold saws, which have reached a high state of perfection; angles are cut off by angle shears, which must be of large size to accommodate 8-inch by 8-inch angles, which have come into use of late years for the flanges of large plate girders. The machine illustrated on page 207 will shear 8-inch by 8-inch angles one inch thick, and is provided with a turn-table so that it can be turned to cut off angles on a bevel and avoid taking up room by skewing long pieces across



A MULTIPLE PUNCH. BUILT BY THE LONG & ALLSTATTER CO., HAMILTON, O.



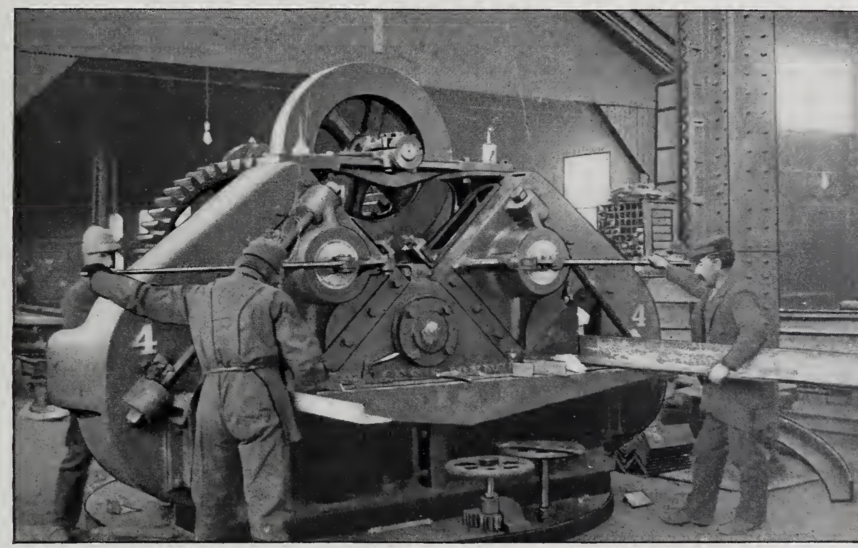
THE SAME MACHINE WITH COPING TOOLS ATTACHED.



THE MAIN TRUSS SHOP OF THE BERLIN IRON BRIDGE COMPANY AT EAST BERLIN, CONN. A STRAIGHT-AWAY TYPE OF SHOP

the shop. This, in itself, represents a very appreciable economy. In one form an electric motor for driving it is directly connected, as is becoming customary in first-class shops, even to the extent of driving small machines with individual motors. While it has been urged by some that this latter is not altogether in line with economy, at least when first cost is considered, it has a distinct advantage in allowing a machine to be placed in the most advantageous and most logical position for use without regard to any line shafting or counter-shafting. The or for other multiple punching, carriages and spacing tables may be employed to automatically locate the rivet holes and save the expense of templets for certain classes of work. Various special designs of multiple punches are employed in many of the larger plants.

The punching of beam and channel flanges is provided for in specially designed punches with overhanging die blocks and roller carriages, and for coping them a number of very heavy machines have been designed. For angle work and other purposes horizontal punches are often used. Reamed

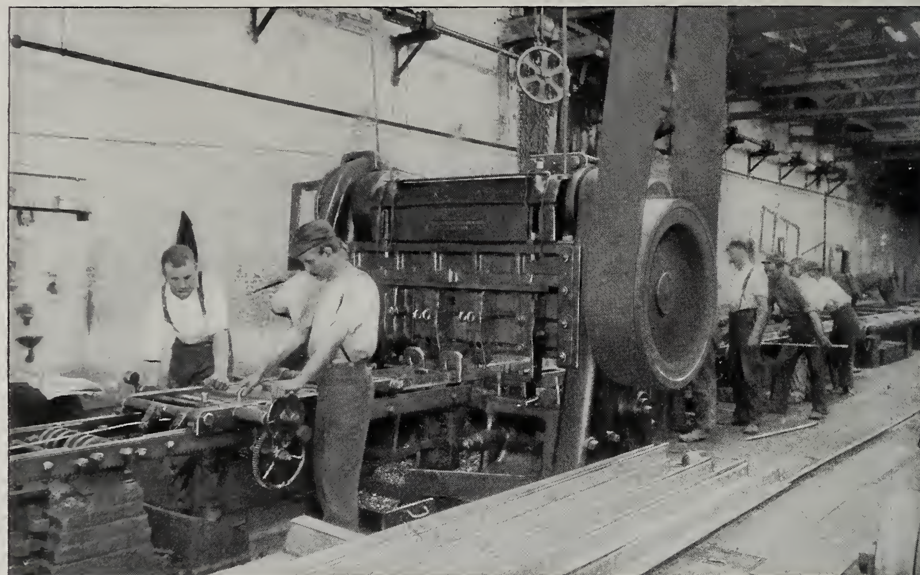


AN ANGLE IRON SHEAR ON A TURN TABLE. BUILT BY THE HILLES & JONES COMPANY, WILMINGTON, DEL.

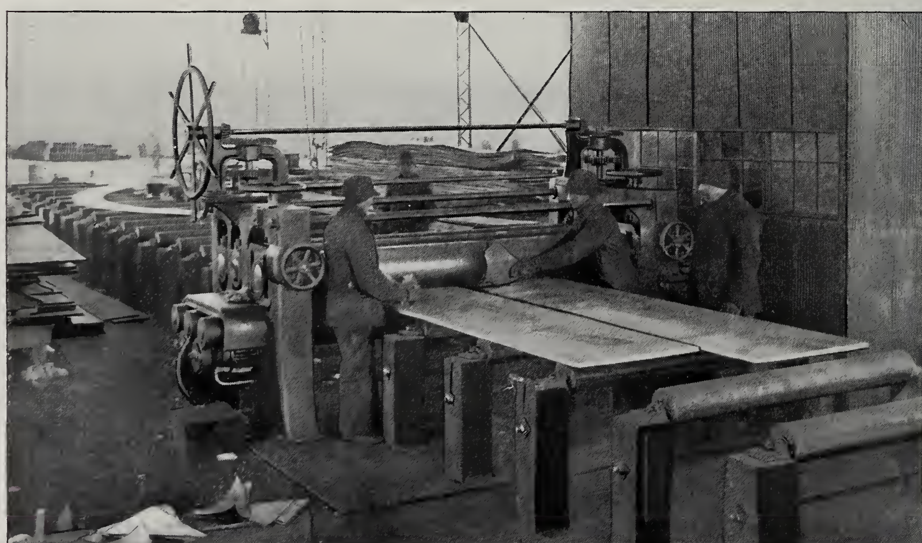
plates and bars are cut off by the ordinary forms of shearing machines, and then all the material is passed along to the punches, if the work is to be simply punched, or punched and afterwards reamed. The multiple punch, shown on page 203, is electrically driven, and has a width of head sufficient to allow the outside punches to be spaced 38 inches apart, while a large number of punches may be added. The sliding head has a spiral spring to counterbalance it, while the wear may be taken up by taper brass wedges which are provided for the purpose. For plate work work has all the holes punched ⅛-inch smaller than required, the subsequent reaming out being done by means of either separate reamers worked by compressed air or with multiple drills arranged on a swinging frame; in some shops this is done with sets of radial drills. This latter method allows the drills to be used when the holes are to be drilled from the solid.

The use of reamed and of drilled work is likely, however, to be entirely abandoned, except in special cases where steel of very high tensile strength must be employed instead of soft-medium

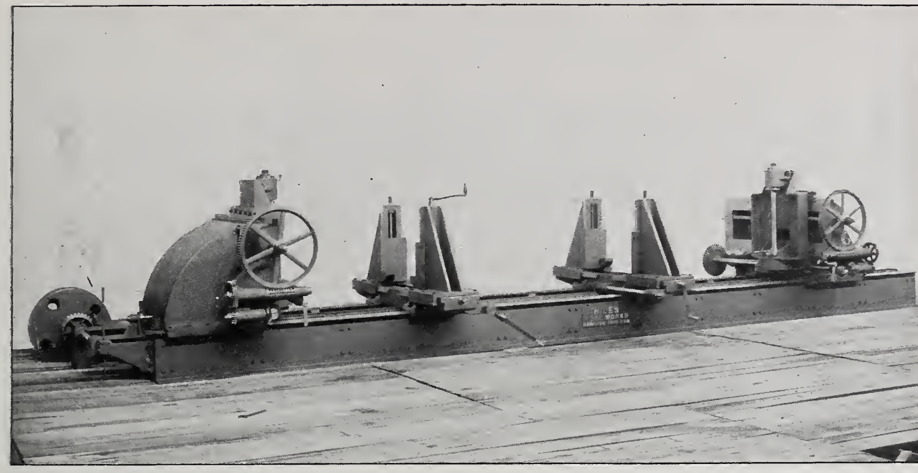
steel with which simple punching is entirely satisfactory. Soft-medium steel, having an average tensile strength of 60,000 pounds, is, moreover, more easily produced and procured and cannot be objected to by those who have so little faith in the integrity of the higher steels as to specify reaming and drilling. Accuracy in the location of punched holes is obtained by the employment of teat punches, the punch marks made by the layers-out being



A MULTIPLE PUNCH AT THE EDGE MOOR WORKS. BUILT BY MESSRS, WM. SELLERS & CO., INCORPORATED, PHILADELPHIA



STRAIGHTENING PLATES IN THE SHOPS OF THE BERLIN IRON BRIDGE COMPANY



A DOUBLE COLUMN MILLING MACHINE. BUILT BY THE NILES TOOL WORKS COMPANY, HAMILTON, OHIO

brought to coincide with the teat on the punch. It is, however, impossible to secure absolute accuracy, and, in some shops, to insure the easy entering of hot rivets, taper reamers, driven by compressed air, are run through every hole, even though the specifications do not call for reaming to even this slight extent. Air reamers are not particularly economical, and it is likely that electrically driven-tools will before long be in use for this purpose.

Previous to any reaming or drilling, the pieces forming a bridge member have been assembled and bolted up, all the surfaces which come in contact having been painted before being brought together. The next step is the most important one in the manufacture of bridges. This is the riveting up of the chord members, posts, lateral struts, stringers, floor beams, and all other built members. The cost of this work varies from ten to twenty per cent. of the total shop cost, so that the employment of the best devices is an absolute necessity. Very seldom does a bridge company employ a purely mechanical riveter, and it is unusual to find any other than compressed air or hydraulic machines in use.

The average number of rivets driven is usually about 3000 or 4000 per day for each machine, although on plain, straight work a record of over 10,000 has been made. The rivet heads should be formed to exact size, and in the case of one large railway company the inspectors are supplied with brass templets to insure properly shaped heads. There is usually a small percentage of shop rivets which cannot be reached by the large machines, and these have generally been driven by hand; but, of late years, a compressed air percussion riveter has been introduced and has come into general use in place of hand driving.

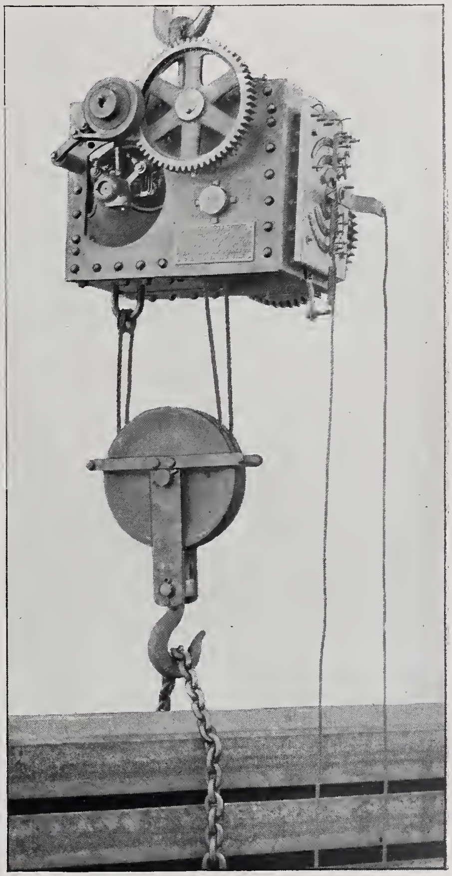
The compressed air for driving air reamers and air riveters is drawn from a boiler-like receiver, which, in the larger shops, is supplied by compressors with compound steam and air cylinders; where smaller compressors are sufficient they may be belted to a countershaft driven directly from the engine, but are preferably located nearer the riveters and can be driven by motors. Riveters operated by electricity have been used to a limited extent, so that it is not improbable that a shop may soon be equipped throughout with electricity. When the riveting is completed, countersunk rivets often require chipping, and pneumatic percussion chippers are employed, as well as for such other chipping as may be needed.

The squaring up of the ends and the facing of mitres and bevels has been almost universally accomplished by the use of rotary planers. These machines have large circular heads carrying thirty

THE RIVETING SHOP OF THE KING BRIDGE COMPANY, CLEVELAND, OHIO

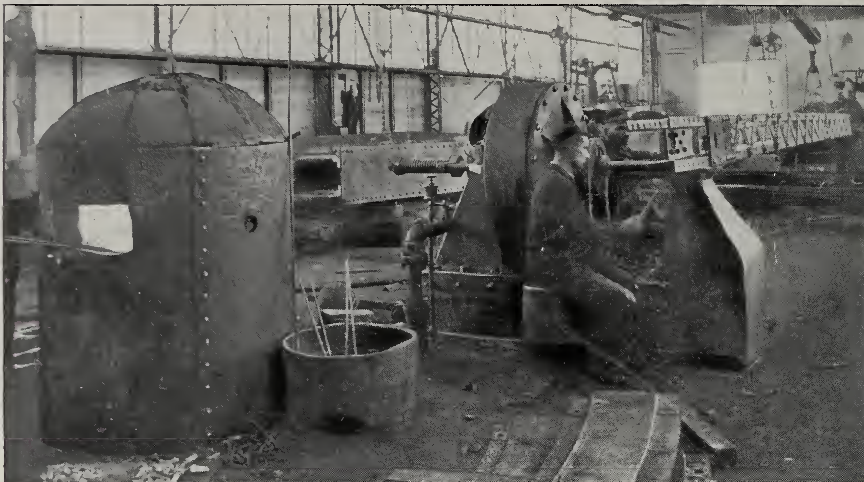
or forty cutters, the head being revolved by means of worm gearing and made to travel horizontally by means of a feed screw operated by a train of gears from the worm shaft, or else by a separate belt. The fact that when a chord member is being planed a cutter engages a thin plate and leaves it almost immediately, before another cutter is engaged, gives a jerky motion to the planer and makes it, in some respects, an unsatisfactory tool. As worm gears are usually constructed, they do not work well for such a purpose, especially after they have become worn, so that it is gratifying to see milling machines substituted for facing bridge members. The one shown on page 209 has two heads, so that both ends of a member may be faced at once, and, as one of the heads can be tilted, bevels and mitres can be faced off accurately. The bed is of such length that pieces 27 feet long can be accommodated, the clamps on the clamping carriage being adjustable for various sizes. The carriages are operated by right and left-hand screws, and the adjustment for distance between the heads is accomplished with a rack, pinion and ratchet, with a fine screw for close setting.

Another machine which is designed to cheapen work in large shops is a double chord boring machine, that is, two drill presses connected together on a long bed, with adjustment for distance between centres and with intermediate supports to prevent deflection of the member that is being bored. Where there is not enough work to warrant the installation of a machine of this kind, a horizontal chord boring machine can be used to advantage, as the raising and lowering bed enables the work to be centered very quickly and easily. Pin holes are first punched out to nearly the required size by the small punch used for rivet holes, by following around a circle with overlapping holes, thus leaving a very narrow cut for the drill press. The use of two cutters on the same cutter bar at the proper distance apart allows the boring of both webs to proceed at the same time. The handling of the material as it progresses from one machine to the other with a very small amount of waste travel is accomplished by several agencies. First there are the electric, compressed air or hand hoists, as the shop owner may elect, attached to trolleys

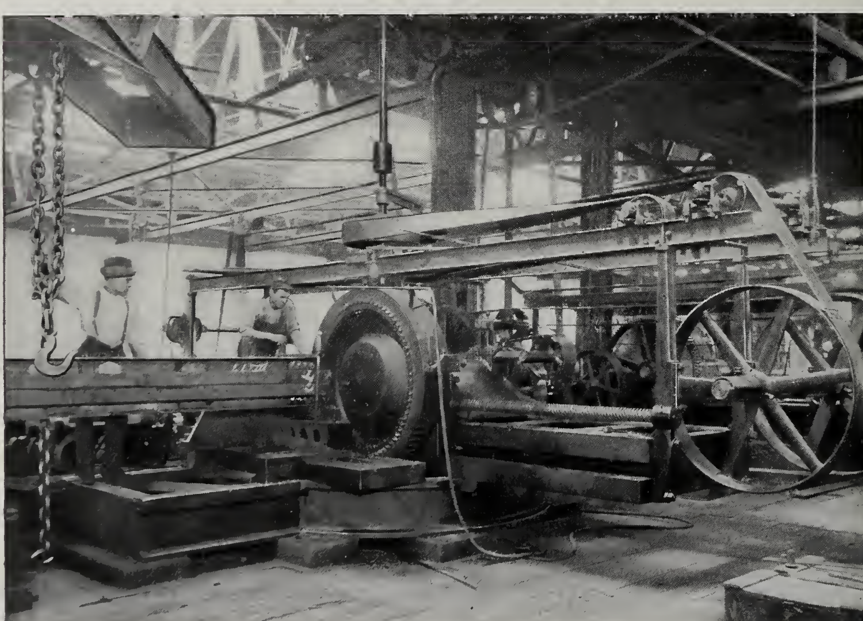


AN ELECTRIC HOIST FOR BRIDGE SHOP USE. MADE BY THE CLEVELAND PUNCH & SHEAR WORKS CO., CLEVELAND, OHIO

which run crosswise of the shop on the bottom chords of the roof trusses for carrying material crosswise. Some large shops have found it desirable to employ small electric cranes for this purpose, which reach from truss to truss, so that in addition to handling crosswise they can move material forward a panel length or two of the shop at the same time. The majority of shops are, however, provided with



A HORIZONTAL STEAM RIVETER. BUILT BY THE BERLIN IRON BRIDGE COMPANY FOR THEIR OWN USE



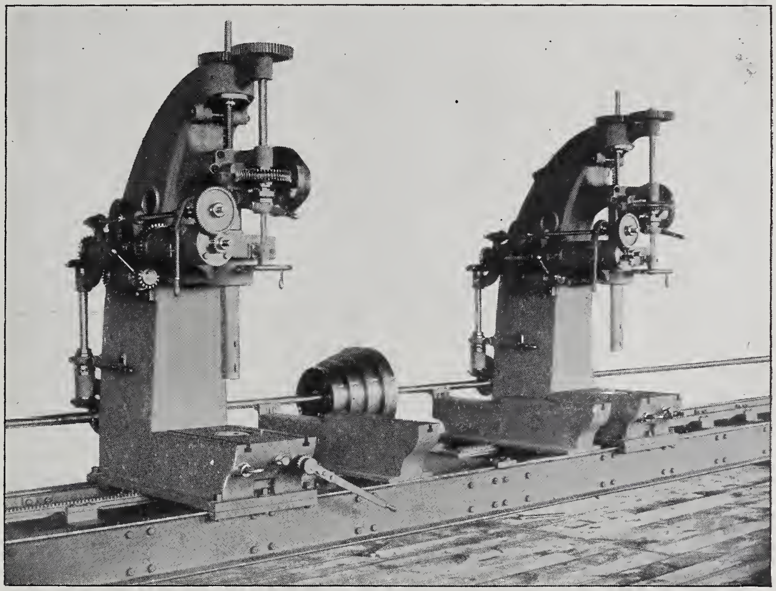
A ROTARY PLANER FACING THE END OF A COLUMN

longitudinal rails on the floor for push cars. Overhead longitudinal rails, from six to ten feet apart, are also provided to carry hoisting carriages or small cranes, or single rails overhead are often used to carry trolleys running lengthwise of the shops. These overhead longitudinal rails are slightly separated where they cross the transverse trolley lines to allow them to pass, the trucks of the longitudinal trolleys and carriages being three-wheeled to enable them to jump over. There are a few cases where large overhead travelling cranes, reaching across the building, have been used, especially for girder shops, but the small, isolated units are usually more convenient and consequently more economical.

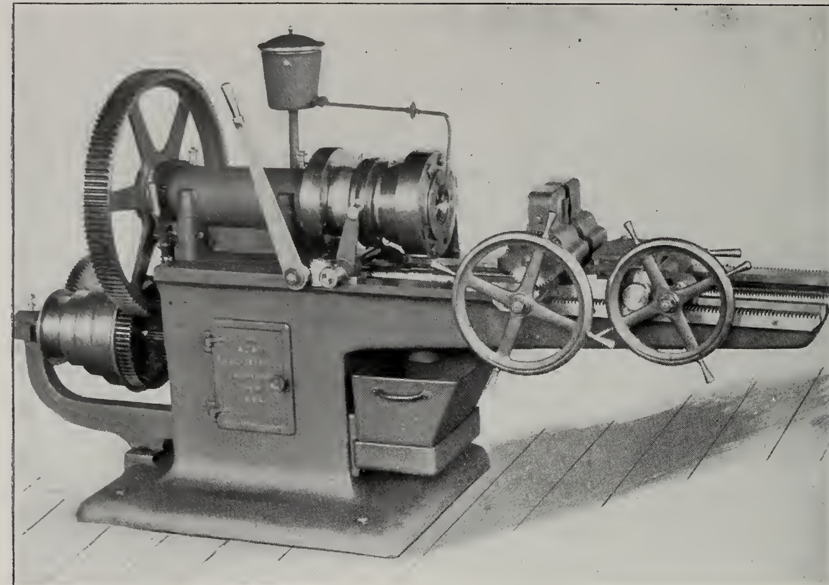
The machine shop proper of a bridge plant usually contains only the machine tools which finish the smaller parts of a structure. The milling machine is supplanting the old planers for planing off bed plates; while for turning large bridge pins, lathes carrying only one tool rest are being supplanted by lathes with two tool rests in front and one in the rear, the front tools to take the roughing cuts and the back one to follow up with the finishing cut.

There are also various other tools, vertical milling machines, shapers, tool lathes, and the like, with labour-saving devices which cannot be described within the limits of this article.

The forge department of a large plant would merit the description due to a separate industry. For the forming of the eight, nine and ten-inch eye bars there are specially designed heating furnaces to properly heat the ends of the bars for upsetting. The upsetting is done by powerful hydraulic machines forming rough heads closely approximating the finished size, which is attained by hammering them in dies under powerful steam hammers, which also form a small hole ready for boring out to full size. The boring is usually done on vertical drill presses, one end of each lot of bars which are of the same length being bored first; then a pin is located on the boring bed at the proper distance from the boring bar to give the proper length and the finished eye is dropped over it to bring the other end to place so that all the bars will be of the same length.



A DOUBLE CHORD BORING MACHINE. BUILT BY THE NILES TOOL WORKS COMPANY



A BOLT CUTTER FOR BRIDGE WORK. MADE BY THE ACME MACHINERY CO., CLEVELAND, OHIO

In some shops, to save time in clamping the bars, a number of the same length are bored at one time.

Smaller steam hammers are employed for ordinary forgings, for forming clevises, pin nuts and various other details. Heading machines are used for making bolts, rivets, and small upsets, while for large upsets on round and square bars hydraulic upsetters are used. Forge fires are still employed to a great extent for welding, bending and forming eyes on small bars, although each year finds less and less for the blacksmith to do and more new machines on the market to do the work. An adjunct to the forge work which is sometimes placed in the machine shop is the bolt cutter or thread-cutting machine. One size is usually employed on bolts and very small rods, while a much heavier machine is used for heavy counter and lateral rod upsets which are to be threaded. Where there is sufficient work to demand it, nut tapping machines are added to the equipment.

One very serious problem which often confronts the manager of a bridge works is the storage of the material for bridges for which the masonry is not completed, or for portions of bridges which are finished while other members cannot be finished on account, perhaps, of shortage of material from the mill. Where there is no delay of this character, the material is painted and loaded directly on the cars under cover of the shop, the cars being run in on a depressed track so that the car platform is level with the shop floor.

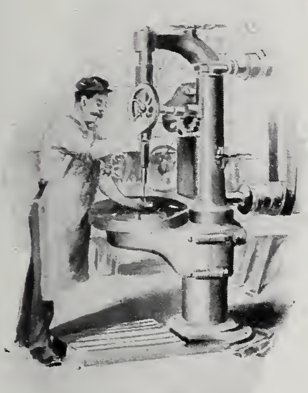
Limited amounts can be stored in the loading section of the shop or in a loading shed, but a large tonnage must be placed in the yards upon skids, and to handle it some shops have numbers of boom derricks to serve the yard and to cover railroad tracks for loading it when required ; others have runways on either side and long-span travelling cranes which reach every part of the storage space and a long stretch of track, while still others employ huge gantry cranes, which are long-span girders, mounted upon a tower at either end, which is provided with wheels to run upon a track on the ground, the whole structure being moved up and down the yard by power, which also operates the

cross travel and the hoist. The travelling crane moving upon runways is easiest maintained in proper working order, and as the rails can be kept level most readily, it can be operated with the least expenditure of power. Whatever scheme is used, electricity can be utilised for power and is gradually crowding out compressed air and steam.

With the completion of the shop work, the limit for the employment of labour-saving machinery in bridge operations has not been by any means reached. Methods of erection have had as much to do with enabling American bridge-building firms to extend their trade as any other feature of the work, and these, so far as they involve the use of machinery, will be treated of in another article which will appear in the February number of this magazine, together with a number of striking illustrations.—THE EDITOR.

POWER LOSSES IN THE MACHINE SHOP

By Charles H. Benjamin



THE object of a machine shop, with its array of glittering machines, its maze of belts and long lines of shafting, is to remove a certain amount of metal from the rough casting. The shop which will do this with the least expenditure of time, labour, and coal is the best shop and will net its owners the largest returns. It may be well to note that the two elements of time and human labour are by far the most important. A good machine must do its work accurately and rapidly and must require the minimum of attendance, since the interest account and the pay-roll far outweigh the expense of power.

Admitting this, the fact still remains that a saving of power is not to be despised, and will help to tip the balance in the right direction. One who has not given the subject special attention would, doubtless, be astonished to learn how small a fraction of the power generated in the engine room finds its way to the points of the cutting tools. Stating the case roughly, for the ordinary machine shop every one hundred indicated horse-power of the engine may be thus distributed:—

Friction of engine	10 H. P.
Line shafting	15 "
Belts and pulleys	15 "
Empty machines	15 "
Cutting metal	45 "
Total	100 H. P.

Even this efficiency would probably be realised only when all the machines were working at their full capacity.

The power required to remove the surface of metal depends on the nature of the material and the shape of the cutting tool. Cast iron consumes the least power of any of the metals in common use, and the harder grades of steel the most power. To remove a pound of cast iron per hour on an engine lathe will take from 0.015 to 0.030 H. P., according to the nature of the tool, with a safe average of 0.025, or one-fortieth of a horse-power.

To remove a pound of machinery steel per hour on the same machine will take about 0.04, or one twenty-fifth of a horse-power. Average engine lathes of from 14 to 20 inches swing will remove from 10 to 20 pounds of cast iron per hour when cutting at full capacity, and consume from ¼ to ½ H. P. in the useful work. In turning machinery steel, the same machines will remove

from 5 to 10 pounds of metal per hour, at an expenditure of from one-fifth to two-fifths H. P.

The power expended in running the machine alone will depend very much on its condition. The writer has seen

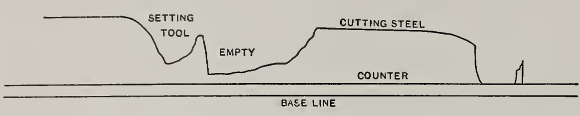


FIG. 1.—AN ENGINE LATHE DIAGRAM

the horse-power consumption of an engine lathe increase from 0.36 to 2.3 H. P. in a few minutes on account of the main spindle becoming dry. The power required to run the average lathe before mentioned, when empty and in fair working condition, will be from 0.04 to 0.16 H. P., exclusive of countershafts, the lower values being for slow speed, and the higher for fast speed. A tightening of the work between the centres may easily raise this to 0.30 or 0.40 H. P. If one-tenth of a horsepower be assumed as an average value of the machine friction and added to the cutting power, the total power consumed by an ordinary lathe will vary from three-tenths to six-tenths H. P., exclusive of counters and belts. Fig. 1 shows a characteristic work diagram from an engine lathe, as drawn by a recording dynamometer.

Experiments made at a prominent American locomotive works on large lathes used for turning driving-wheels and driven by electric motors, showed the average power consumed by an 84-inch wheel lathe to be 1.75 H. P., and the average total power used when cutting, 5.8 H. P. In considering this extraordinarily large result, it is enough to say that the tools in this shop are worked to their full capacity and remove more metal per hour than is generally believed possible. A number of tests on different lathes, conducted by Professor J. J. Flather, have shown an average total horse-power of 0.57, the lathes ranging in size from 12 to 80 inches swing. A series of experiments made by the writer on nine different engine lathes, ranging in size from 12 to 22 inches swing, gave an average total cutting power of 0.21 H. P., the machines in this case running under ordinary conditions and not loaded to their full capacity.

It may, then, be safely assumed that an allowance of ¼ H. P. for the average load, or ½ H. P. for the maximum load on each engine lathe in an ordinary machine shop will be sufficient.

A number of different experiments with an iron planer, 24″ × 24″ × 6 ft., have shown a consumption of 0.035 H. P. for every pound of cast iron removed per hour and a consumption of 0.065 H P. for every pound of machinery steel removed per hour. It is more difficult to set a planer tool correctly, and it is more liable to become dulled than the lathe tool. A planer of the above size may remove 20 pounds of soft steel or 30 pounds of cast iron in an hour, consuming, in cutting metal, 1.3 H. P. on the steel and 1.05 H. P. on the cast iron. These, however, are large values, and in ordinary work this machine would not consume over ½ H. P.

The power required to drive the empty planer is variable, being greatest on the return stroke on account of the faster speed, and rising to a maximum at the instant of reversal. This can best be understood by reference to Fig. 2, which shows diagrams taken with a recording dynamometer from the planer above referred to, when empty and when cutting cast iron at the rate of about 25 pounds per hour.

It may be seen that the time of return is just one-half that of the forward motion. The power used in return is the same in both diagrams (*a*, *a* in the figure). The power used in cutting is greatest at the beginning of each stroke (*c*, *c* in the figure), but this may be due to a difference in the depth of cut or hardness of the metal. The jumps in pressure due to reversal are about the same in both diagrams, but those at the end of the return (*d*, *d*) are much greater than those at the end of the forward

motion (*b*, *b*). The average power consumed is about 0.50 H. P. for the empty machine and 1.00 H. P. for the total when cutting. The maximum power at the instant of reversal is 2.8 H. P., but much of this will naturally be supplied by the stored energy of the line shafting. With a heavy planing machine taking a light cut, more power will be used in running back than when cutting.

Six experiments with the planer before mentioned show an average horse-power for the empty machine of 0.25 when running forward, and 0.55 when running backward, with a general average of 0.35 for the whole time. This would give a total consumption of power when cutting metal of 0.50 to 1.65 H. P., with a probable average of about one horse-power on ordinary work.

From the experiments at the locomotive works before referred to, the following results were obtained in the case of large planing machines:—

TABLE I

Size.	Motor & Shaft.	Horse-Power. Empty Machine.	Total Cutting. Min.	Total Cutting. Max.	Ave.
62 in.x35 ft	4.4	11.4	20.6	21.6	21.1
62 in.x35 ft	---	5.8	23.0	26.0	24.5
36 in.x12 ft	2.7	3.0	11.3	13.8	12.5
24 in.x13 ft	1.95	4.3	---	---	8.0
36 in.x18 ft	3.2	4.3	---	---	16.7
56 in.x35 ft	4.6	9.9	13.0	13.7	13.3
56 in.x24 ft	4.56	6.0	16.0	17.7	16.8

In all the above planers two tools were used and the machines were worked to their full capacity.

Shaping machines will ordinarily remove more metal per horse-power per hour than the larger planers. This is probably due to the fact that in the former case the light tool carriage consumes less power than the heavy platen of the planer with its load. The average amount of power required to run a 16-inch shaper is about 0.15 H. P. when empty, and about 0.65 H. P. when removing 10 pounds of cast iron per hour. Five different shaping machines, varying from 4 inches to 29 inches stroke, showed, by test, to require an average of 0.48 H. P.

Drill presses such as are ordinarily used in shops require but a small amount of power, and most of this is consumed in driving the machines alone; ¼ H. P. would be a fair allowance for an upright drill of 24 inches swing when drilling holes not over one inch in diameter. In drilling steel at the full capacity of the drill, this has been known to increase to ¾ H. P.

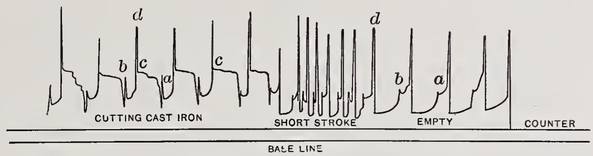


FIG. 2.—PLANER DIAGRAMS

Milling machines of the universal type, with centres swinging 10 inches in diameter, when running empty consume an inappreciable amount of power, usually less than one-twentieth H. P. The amount of metal cut per hour by such a machine is ordinarily much less than with lathes or planers, and the power required per pound is much greater. Prof. Flather gives the horse-power consumed by the milling machine per pound of metal per hour as 0.14 for cast iron, 0.10 for bronze, and 0.30 for tool steel, or about four times as much as would be used by a planing or shaping machine under the same circumstances. The total power used by the milling machine mentioned above would vary from one-twentieth to one-half H. P. In estimating the power that will be required to drive the tools in an ordinary machine shop doing medium and light work, the preceding figures show that an allowance of from ¼ to ½ H. P. for each engine lathe and shaper, 1.0 H. P. for each planer and ¼ H. P. for

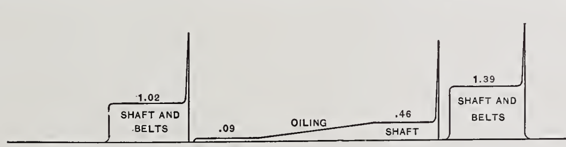


FIG. 3.—A SHAFTING AND BELT DIAGRAM

each drill press and column milling machine would be ample. The machines would never be run all at one time at full capacity.

A comparatively small amount of power is consumed by an ordinary counter-shaft, when in good condition, but the combined losses due to the loose pulleys, the clutches and the pull of belts on counters and line shafting are considerable. This can be seen clearly in Fig. 3, which shows a diagram drawn by a recording dynamometer for the shafting and belts in a machine shop under the writer's care. The line shaft in this shop is 1 15-16 inches in diameter and 90 feet long, and is supported by twelve drop hangers with ball and socket joints. This shaft drives nine engine lathes, a planing machine, two shapers, two drill presses, a milling machine, and several smaller tools.

To carry these various machines, thirty belts, having an average width of 2½ inches, run from the line shaft to the counters of the machines. The extreme right of the diagram shows the power required to run the whole overhead system of shafting, belting, clutches and loose pulleys, without special oiling, the horse-power developed being 1.39. The belts were then removed from the pulleys and hung up so as not to touch the shaft, when the second line was traced, giving a horse-power of 0.46.

This leaves a difference of 0.93 H. P. for the friction of the counters and belts when the machines are not running, or twice the friction of the line shaft. The inclined line shows the effect of flooding the bearings of the line shaft with a thin machine oil, the power falling to less than 0.10 H. P. Replacing the belts on the pulleys gave the last line with a horse-power of 1.02. The difference between this last and the friction of the shafting is still 0.93 H. P., as at first, and shows the power wasted in belt transmission.

A test made on this same line several days later, with the machinery at work, about eight machines being in operation with ordinary loads, showed a horse-power of 2.51. Subtracting 1.39 for the horse-power of shafting and belts, leaves 1.12 H. P. for the power consumed by the eight machines, or about 0.14 H. P. per machine. The percentage of power consumed by shafting and belts is thus 55 per cent., leaving 45 per cent. for the machines themselves. A subsequent test when fifteen machines were in operation, with comparatively heavy cuts, gave results as shown in Table II.

TABLE II.

Kind of Machine.	Material.	Size of Stock.	Depth of Cut.	Horse Power
Milling	Wr't iron	1.25 in square.	0.08 in.	0.092
Lathe.	Mach. steel	0.7 in dia.	0.07 "	0.183
"	" "	0.86 " "	0.05 "	0.183
"	Cast iron	7.48 " "	0.04 "	0.183
"	Mach. steel	1.0 " "	0.10 "	0.183
"	" "	0.56 " "	0.11 "	0.274
"	Cast iron	11.75 " "	0.03 "	0.137
"	Mach. steel	1.02 " "	0.04 "	0.320
"	" "	1.58 " "	0.15 "	0.323
"	Cast iron	17.13 " "	0.12 "	0.137
Planer	" "	48 in. stroke	0.15 "	0.960
Shaper	Mach. steel	13.5 " "	0.06 "	0.274
"	Cast iron	12.5 " "	0.06 "	0.274
Drill	Mach. steel	1 in. drill	----	0.274
"	" "	⅞ " "	----	0.046

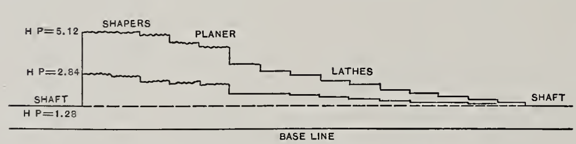


FIG. 4.—A TYPICAL SHOP DIAGRAM

The total power used by these fifteen machines was 3.84 H. P., or 0.255 H. P. per machine. The total power used by shafting and belts was 1.28 H. P. This experiment gives just 75 per cent. of power consumed by the machines and 25 per cent. by the overhead losses, and probably represents the best that can be expected. Assuming that the power consumed in cutting the metal is three-fourths of the power used by the machine, the work will be distributed about as follows:—

Shafting losses	12.5	per cent
Counters and belts	12.5	"
Machines	18	"
Useful work	57	"

Fig. 4 shows graphically the results of the test just mentioned, the upper line indicating the increase of the load as the cutting machines were successively thrown on, the intermediate line the effect of throwing in the same ma-

chines when empty, and the lowest line the constant loss due to the overhead transmission.

During the winter of 1898-99 several tests were made under the direction of the writer on the power consumed by the shafting, belts and machines in several different rooms of a large manufacturing establishment. The results may be summarised as follows:—

Room No. 1.—This room was used as a repair and tool room, and contained the following equipment:—

Shafting 1 15-16″ in diameter and 100 feet long, running at 175 revolutions per minute.

Eleven journals on main shaft, 12 feet apart.

Forty-one belts of an average width of 3 inches.

Four medium drill presses. Five medium shapers.

Six engine lathes, 12″ to 22″ swing. One wood lathe, 12″ swing.

Two surface grinders.

One 18″ planer. Three medium milling machines.

Emery-wheel and grindstone.

The test began at 10.45 A. M., and continued until 5 P. M. Only a few machines were running at a time,—from two to five lathes, one of the milling machines, a drill press and one of the grinders. The average power consumed by the shafting and belts was 3.36 H. P. and by the machines 1.65 H. P., a total of 5.01 H. P. This room used, therefore, one-third useful and two-thirds waste work.

Room No. 2.—This room contained the following machinery and shafting:—

Shafting, 2″ in diameter and 85 feet long; 311 revolutions per minute.

Twelve journals on main shaft, three of them roller bearings.

Thirty-four belts of an average width of 1¾ inches.

Eleven small automatic screw machines.

Two milling machines, 8″ × 24″.

Seven engine lathes, 13″ and 14″ swing.

Two turret lathes.

The test began at 6.40 A. M. and continued until 4.55 P. M. In this case about twelve machines were running most of the time, but the load was variable. The total average power used was 8.93 H. P., of which 2.84 H. P., or about 32 per cent., was consumed by the shafting and belts.

Room No. 3.—This room contained shafting and machinery as follows:—

Shafting, 75 feet long, 146 revolutions per minute, nine journals.

Nineteen belts having an average width of three inches.

Three special lathes. Nine drill lathes.

One engine lathe. Three drill presses.

Horizontal drill grinder, emery-wheel, etc. The average number of machines running was five, and the load was extremely variable. The test began at noon and lasted until 5 P. M. The total power used was 2.31 H. P., of which 1.33 H. P. was consumed by shafting and belts, or a loss of 57 per cent.

The experiments on these three rooms show about what may be expected in ordinary practice, when no special effort is made to keep all the machines in operation or to load them to their full capacity.

In April, 1899, a test was made at a pattern shop to show the power consumed by woodworking machinery. The following list indicates the shafting and machinery tested:—

Shafting, 1 15-16″ in diameter, 70 feet long, 294 revolutions per minute.

Thirteen belts having an average width of 2.32 inches.

Nine journals on main shaft, 8 feet apart.

Seven wood-turning lathes, 10″ to 14″ swing.

One pattern-maker's gap lathe.

One band saw, 36″ wheels.

One circular saw, 8-inch.

One buzz planer, 14″ head.

A summary of the results of several tests is subjoined:—

Buzz planer, empty	0.81	horse-power
Buzz planer, cutting	1.51	"
Circular saw, cutting	0.80	"
Band saw, cutting	0.22	"
All machines, cutting	3.70	"
Shafting and belts	1.87	"
Shafting alone	0.67	"

These experiments show the following distribution of power:—

	Horse-power.	Per Cent.
Shafting alone	0.67	12
Belts and pulleys	1.20	22
Machines, cutting	3.70	66
Total	5.57	100

In a series of experiments made in 1895-96 and first reported to the American Society of Mechanical Engineers, the writer determined the power losses in twelve different machine shops. In six shops using heavy machinery the average power consumed by engine, shafting and belts was 62 per cent. of the whole, and in six shops using light machinery, 55 per cent. was the average loss. Nearly all the shops were running at what they called full capacity.

Table III. shows the distribution of the waste and useful horse-power in ten of these establishments. The friction horse-power per counter-shaft is quite uniform in these different cases, being about 0.6 H. P. for the heavy work and 0.2 H. P. for the light work. The useful horse-power per machine naturally varies considerably, but averages about 0.5 H. P. per machine. This corresponds well with the figures that have been given previously.

TABLE III.

Nature of Work.	Friction Horse-Power.				Useful H.P. Per Machine.
	Per Bearing.	Per Counter.	Per Belt.	Per Cent. of Whole.	
Boiler shop	0.550	0.538	0.477	65	0.310
Bridge work	0.337	0.606	0.521	80	0.164
Heavy mach'y	0.581	0.665	0.453	57	0.707
Heavy mach'y	0.799	0.600	0 475	54	0.627
Average	0.567	0.602	0.481	64	0.452
Light mach'y	0.204	0.155	0.095	51	0.790
Small tools	0.689	0.127	0.119	54	0.809
Small tools	0.240	0.121	0.113	52	0.881
Sewing mach's	0.397	0.269	0.208	57	0.180
Sewing mach's	0.406	0.172	0.154	69	0.181
Screw mach's	0.633	0 291	0.235	47	0.296
Average	0.428	0.189	0.154	55	0.406

After studying these apparently excessive losses due to the ordinary system of transmission by belts and pulleys, one naturally turns to electrical transmission for relief. It is not best, however, to be too sanguine in regard to the newer way. The experiments made in the locomotive works, which have been already referred to in this article, show the power consumed by heavy machine tools when driven by independent motors.

An average of sixteen tests on different lathes, planers, slotting machines and boring mills gives 8.85 H. P. for the machine and work, and 2.35 H. P. for the motor and counter-shaft. Thus we see that when the machines were run under the most favourable conditions, the motor and its shaft consumed nearly 25 per cent. of the total power used, which is fully as much as would be lost in well-constructed line and counter-shafts.

When the group system of electric driving is resorted to for smaller machines, we have a mixture of the old and the new. Table IV. gives a summary of the principal results obtained from tests of machine tools where these were driven in groups by electric motors.

TABLE IV.

Length of line shaft in feet	60	100	60	80
Diameter of line shaft in inches	2 15-16	2 7-16	2 15-16	2 15-16
Speed of shaft, revolutions per minute	150	150	150	150
Number of machines	13	23	17	8
Total horse-power	34.2	40.7	31	21.9
Horse power of motor and shafting	15.1	12.1	88	5.8
Horse-power of machines	19.1	28 6	23	16.1
Average horse-power per machine	1.47	1.24	1.35	2.01
Per cent. of total horse-power for motor and shafting	44	30	25.8	26.5

We may, then, safely predict a loss of at least 25 per cent., whether wires or belts and shafting be the transmitting agent. The extraordinary losses shown by some of the shops referred to in Table III. were due in most cases to an excessive use of line shafting, one estab-

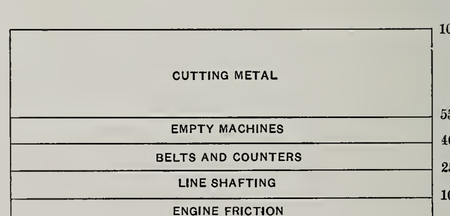


FIG. 6.—POWER DIVISION IN AN ORDINARY MACHINE SHOP

lishment having nearly 1500 feet of shafting to drive 70 machines and losing 80 per cent. of the power on its way. In some cases the alignment and general condition of the shafting was poor.

The principal arguments for the introduction of electrical transmission have not to do with saving of power, and may be thus summarised:—

1. Better arrangement of machinery to facilitate handling of work.

2. Clear head room for the use of electric cranes and small hoists.

3. Light and cleanliness.

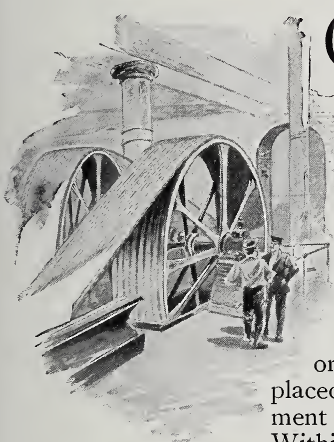
4. General flexibility of the system for changes and extensions.

5. The use of electricity for other purposes than power.

The diagram in Fig. 5 shows the probable division of power in an ordinary machine shop, and is self-explanatory.

THE UNION OF ELECTRIC LIGHTING AND TRACTION PLANTS

By Alton D. Adams



CONSOLIDATION is, at present, the most notable tendency among electric plants for public supply. In many cases several small stations that have furnished electric light and power in a town or city are being replaced by larger equipment at a single point. Within the larger plants a similar process is going on, leading to the smallest practical number of engines and electric generators. The best engineering effort is also directed to apply each generator to any part of the electric load and to give all generators the property of operation in multiple.

The object of these changes is to secure the smallest labour and fuel expense per unit of energy output. Concentration of large capacity in a few generating units greatly reduces the labour charge, and the use of large, economical engines at nearly full load insures the smallest possible consumption of steam.

Central station loads are subject to wide variations at different hours of the day, and to momentary fluctuations during their entire runs. Through a large part of each twenty-four hours the public demand for current is comparatively small, while for about two hours per day it is several times the average.

The storage battery here offers its advantages in helping to maintain a steady station pressure under fluctuating demands, to keep operating engines fully loaded by the absorption of energy when the outside requirements are small, reduces the necessary generator capacity by discharging at times of maximum public requirement, and permits a stoppage of machinery during the hours of minimum load. The generating plant or suitable points in the territory served, called substations, may serve to locate the battery, according to the area and arrangement of each particular system.

Dynamos at the main station frequently supply direct current only, which gives a high economy in the service of near-by loads, say, within a radius of one mile, but is commonly at a decided disadvantage with loads several miles distant from the station. Alternating-current dynamos of high pressure are employed exclusively at the generating plant in many cases, enabling distant loads to be economically reached; but they introduce a large and nearly constant transformer loss between the main station and its heavy adjacent

laods. The latest and best central station practice secures all of the benefits of both the direct and alternating current distribution without involving the disadvantages of either, maintaining, at the same time, the properties of multiple operation, and either service from any generator. These opposite results are obtained with electric generators which have a commutator for direct current, and collector rings for alternating current, connected to the same armature winding. The commutators of the generators are connected in multiple for the direct current supply, and the transformers, used to raise the pressure of energy from the alternating current collector rings, have their secondaries in multiple. Any generator may thus furnish output to the amount of its capacity in either direct or alternating current, or in any proportion of each at the same time.

Consolidation for public electric plants may be considered as having reached its limits in the development of a single generating station from each large centre of propulsion, the reduction of engines and dynamos in each station to the smallest practical number, and the combination, in each unit, of capacity for either direct or alternating current service.

The union of public electric light and power plants with those now maintained exclusively for traction purposes seems to be the next inevitable step in the march of power centralisation. Electric traction plants have remained unique in their devotion to the single purpose of tram-car propulsion. It is true that a small amount of energy is diverted for heat and light in the cars and car-houses, and in some cases along the line of the railway, but the general practice has been to refrain from public light and power supply. Thus the design of electric traction plants for a single kind of service has resulted in marked uniformity in their equipments. In almost every case direct current generators, operated in multiple and of about 500 volts pressure, constitute the entire dynamo plant. In the more recent stations the generating equipment, like that in public light and power plants, has been reduced to the smallest practical number of large, direct-connected engines and dynamos. The several steam plants of moderate size formerly common in large traction systems are now giving place to one large generating station, in each case supplemented with small substations of storage batteries. Batteries also find a place at the main station for the same purposes as in light and power plants.

The pressure of about 500 volts, so generally adopted, is well adapted to the purposes of distribution for the distances usually covered by the tram-car system of a single town or city, but involves an undue outlay for conductors, or too much loss of pressure and energy, on many of the cross-country lines that are now multiplying so rapidly. To secure economical distribution over the wide areas that are now coming to depend on a single generating station for electric traction purposes, alternating current dynamos of high pressure are being introduced. The current from these is received at substations near the distant points of delivery and is reduced through transformers and rotary converters to direct current of about 500 volts pressure. Many electric traction plants have thus reached a stage of development where, as in light and power stations, both direct and alternating current must be furnished to economically meet the conditions of service, and recourse must be had to the kind of generator which can furnish its output in either direct or alternating current. It is, therefore, evident that both public electric supply stations and traction plants have reached, or are tending to, the same general character of equipment.

Most, if not all, of the advantages sought by the consolidation of several small generating plants into one large one and the substitution of a few large engines and dynamos for many of less capacity may be greatly increased by the union of electric light and traction plants. The times of maximum evening loads in lighting and traction systems do not exactly coincide, so that

the combination of these loads would materially extend the time during which the great bulk of station equipment could be in use each day. The large all-day and late-evening load of tram-cars would increase largely the ratio of the average, compared with the maximum load, in a combined lighting and traction plant, over that existing in a simple lighting station, and the economies incident to a few large, direct-connected generating units, as to fuel and labour, would be especially advanced in the combined plants.

Stations for combined electric light and traction service have thus far been inaugurated in but few instances, because it has seemed impractical to draw current from the same machinery for both services, but means and methods are now at hand by which either high or low pressure services for public lighting and power can be supplied by the same dynamos that operate for electric traction on either short or long distances. The design of machinery and systems for electric lighting is regulated, to a large extent, by the practical voltage of incandescent lamps. From an early period in its development to within about two years of this time the highest pressure at which incandescent lamps could be operated has remained at about 110 volts. Central station supply of low pressure, direct current, is generally conducted on the three-wire system, which allows a maximum pressure of from 240 to 250 volts on the lines, according to the loss in conductors, for 110-volt lamps. The maximum station pressure on the direct supply is, therefore, a little more than twice the voltage of the lamps used.

After remaining fixed for about fifteen years, the voltage of commercial incandescent lamps has been doubled at a single step, and they are now regularly sold for pressures up to 250 volts. This improvement of incandescent lamps makes it practical to raise the pressure of the three-wire system to fully 500 volts, or about that at present used in nearly all traction plants. It is, therefore, evident that three-wire service to incandescent lamps and stationary motors may now be supplied from the same equipment that furnishes current for traction purposes. A storage battery will be necessary to steady the station pressure and for the other purposes above pointed out. A separate system of conductors is necessary for the traction service, both because of its variation as to location from the stationary motor and lighting load and by reason of its highly fluctuating character.

For direct-current service only, suited to both lighting and traction over distances up to about five miles from the generating plant, dynamos of about 250 volts each, connected on the three-wire system, should be used, traction current being taken from the outside connections at somewhat more than 500 volts.

If, as is frequently the case, parts of the lighting and traction loads are at distances from the main station that make higher pressures necessary for economical transmission, generators competent to deliver their capacity in either direct or alternating current should be used. The pressure of each of these generators should be about 250 volts, as in the case just mentioned, and their commutator terminals should be connected in parallel on the three-wire system for direct current supply to near-by loads. The alternating current terminals of these generators should be connected to one bank of transformers whose secondaries work in parallel on lines to the distant substations for traction service, and to another bank of transformers which supply conductors for incandescent lamps and stationary motors beyond the direct-current radius.

ILLUMINATING AND FUEL GAS

ITS DANGERS TO PUBLIC HEALTH AND HOW TO AVOID THEM

By Wm. Paul Gerhard, Consulting Engineer for Sanitary Works

SOME time ago, at a meeting of the American Public Health Association, a committee was appointed to investigate the subject of illuminating gas in relation to health, and it was this that prompted the preparation by the author of what is given in the following pages for presentation lately before that society.

Owing to recent progress in the art of manufacturing gas, this subject is now much more difficult to treat than it was twenty or thirty years ago, when scarcely anything else but the ordinary lighting gas, manufactured by a process of distillation from coal, was known. About twenty years ago, gas companies began the manufacture and introduction of the so-called water gas. Several investigations were conducted and reports made at that time with regard to the dangers involved in the new gas. Still more recently, not more than five years ago, the manufacture of acetylene gas from calcium carbide began, and whilst its use is, at present, largely confined to isolated buildings not in reach of city gas works, it promises a rapid development within the next decade.

The aëriform mixture, commonly known as gas, is nowadays used not only as an illuminant, but also as fuel, for heating, cooking and industrial purposes; in a few places a special quality of gas not fit for illumination is distributed to consumers for use as gaseous fuel; and in others what is known as natural or rock gas is introduced into houses for like purposes.

At the present time, we may distinguish the following kinds of gas:—1. Natural gas; 2. Coal gas; 3. Water gas; 4. Carburetted or luminous water gas; 5. Air or naphtha gas; 6. Acetylene gas; 7. Gas from oil, wood, resin, etc.

Natural or rock gas consists of an accumulation of hydro-carbons found in nature below the surface of the earth. It sometimes flows freely at the surface, as in the eternal gas fires at Baku, Russia, or else it is liberated by boring. It is really the same as marsh gas or light carburetted hydrogen, known in mines as fire damp. In burning, it usually produces little light, the flame being bluish-yellow, and is, therefore, suitable principally as fuel gas, though some natural gas contains illuminating or heavy hydro-carbons, and can be used for lighting. Mixed with ten times its volume of air, this gas ignites with a violent explosion when a light is applied. The composition of natural gas varies, as seen from the following three analyses:—

	I	II		III
Marsh gas	49.58	75.16	Marsh gas	60-89
Hydrogen	35.92	14.15	Hydrogen	4.79-22.5
Ethylhydride	12.30	4.80	Ethylhydride	4-18
Ethylene	0.60	0.60	Ethylene	0.56-2.94
Oxygen	0.40	1.20	Carbonic oxide traces to	0.26
Carbonic oxide	0.40	0.30	Carbonic acid	0.28-0.66
Carbonic acid	----	0.30		
Nitrogen	----	2.89		

Coal gas is made from bituminous coal, by a process of distillation in closed retorts. It may be termed the ordinary illuminating gas, as it was the first lighting gas manufactured and distributed on a large scale. Such coal gas is really a more or less purified mixture of a number of distinct gaseous combustible substances, of which some are luminous, while others burn with non-luminous flame. Its manufacture embraces three principal processes, viz., distillation, condensation, and purification.

When coal gas is distilled in retorts

the resulting vapours which contain hurtful impurities are first condensed, and tar and water are thereby removed; the several subsequent processes of condensation remove carbonic acid and some ammonia; in the washers and scrubbers the remaining ammonia is removed, while the purifiers free the gas of carbonic acid, sulphuretted hydrogen, and other gaseous sulphur compounds, by means of lime and oxide of iron. The composition of purified coal gas is about as follows:—

I.	Per Cent	II. (Pettenkofer)	Per Cent	III.	Per Cent
Hydrogen	50.2	Hydrogen	49	Hydrogen	40-50
Marsh gas	29.8	Marsh gas	36	Marsh gas	35-45
Carbonic oxide	7.9	Carbonic oxide	7	Carbonic oxide	4.5-7.5
Heavy hydro-carbon	4.3	Heavy hydro-carbons	8	Olefiant gas	4-8
Nitrogen	7.8			Small amounts of carbonic acid.	
	100.0				

A few actual analyses of coal gas are here quoted, the differences being due to the kind of coal used in the manufacture of the gas:—

Boston Coal Gas (Nichols)	
Marsh gas	40.0
Hydrogen	34.8
Nitrogen	14.2
Carbonic oxide.	7.0
Illuminants	3.4
Oxygen	0.5
Carbonic acid	0.1

	London Coal Gas (Letheby)	
37.41	Light carburetted hydrogen	39.5
46.38	Hydrogen	46.0
3.72	Condensible hydro-carbons	3.8
5.53	Carbonic oxide	7.5
6.19	Aqueous vapour	2.0
0.25	Oxygen	0.1
0.52	Nitrogen	0.5
	Carbonic acid	0 6

Water gas or hydrogen gas is made by passing steam over incandescent carbon or glowing coals. The resulting gas is odourless and non-luminous, but owing to its large amount of hydrogen it burns with great heat; hence this gas is excellent for fuel purposes. The coal used in the process is anthracite coal. Theoretically, water gas is composed of 50 per cent. hydrogen and 50 per cent. carbonic oxide. The latter is the dangerous element in all gas.

Carburetted or luminous water gas is a mixture of pure water gas and petroleum, naphtha or cannel gases, the latter being heavy hydro-carbons, mixed with it to give it luminosity, to render it fit for lighting purposes, and to give it a distinct odour. This is done by the so-called carburetting process. Since about twenty years a great many gas works manufacture and supply this composite gas, the chief reasons for preferring this process being the reduction in first cost of the works, the easier purification, the smaller area required for manufacturing, the possibility of using coke, the doing away with some of the side products or residues, and the cheapening in the cost of manufacturing the gas.

Many different processes are in use for making carburetted water gas (Lowe, Strong, Gwynne-Harie, Harkness, Tessie de Motay) and the composition of the manufactured gas, as well as its lighting qualities, vary greatly. A few analyses are quoted as examples:—

Composition of Water Gas

I.		III.		II.	
Carbonic oxide	28.25	Hydrogen	38.05	Hydrogen	30.34
Illuminating hydro-carbons	12.82	Marsh gas	11.85	Marsh gas	20.55
Marsh gas	21.45	Carbonic oxide	29.40	Carbonic oxide	27.46
Hydrogen	30.3	Carbonic acid	0.10	Carbonic acid	0.35
Nitrogen	6.85	Oxygen	0.10	Oxygen	0.26
Carbonic acid	0.3	Nitrogen	3.71	Nitrogen	[illegible].56
	99.97	Olefine	9.29	Illuminants	12.48
		Paraffines	7.50		
			100		

Air or machine made gas, or carburetted air gas, is a simple mixture of atmospheric air with the vapours of naphtha, benzol, petroleum or gasoline. The use of such gas is largely confined to the lighting up of isolated buildings not in reach of gas works. The apparatus for its manufacture consists, in its simplest form, of a blower and a generator. The latter is placed in a brick vault, at a good distance from a building, and is filled with refined gasoline,

which is a very volatile, inflammable liquid. A blower or air pump is placed in the cellar of the building; this is operated either by a suspended weight, which must be wound up like the weights of a clock, or by a wheel, driven by water. It forces air into the generator, which there takes up the vapours of the naphtha, and, so enriched, is delivered to the house to be consumed.

It burns with a tolerably good luminous flame; the gas being very heavy, it flows comparatively slowly; hence large pipes and burners are required. The flame is seldom free from smoking. The gasoline itself from which the gas is made is a very volatile and highly inflammable liquid which gives off vapours at ordinary temperature. Mixed with a certain proportion of air, the machine or air gas is very explosive.

Acetylene gas is the latest comer in the field of gas manufacture. This gas has been known chemically since 1836 (Edmund Davy, chemist) as the most brilliant of illuminating gases. In 1861 the chemist Woehler, and in 1862 Berthelot, prepared the gas in the laboratory from calcium carbide and water. In the latter part of the year 1892, the French chemist, Henri Moissan, made small quantities of calcium carbide in a laboratory furnace. But the commercial manufacture of crystalline carbide on a large scale in electric furnaces was discovered accidentally in May, 1892, by an electrician, Thomas L. Willson, of Canada. Before that time calcium carbide was a very expensive chemical, but after Willson's discovery its price dropped to less than 5 per cent. of the earlier figure.

Acetylene gas has a very peculiar, easily detected, garlic-like odour; it is an ignitible gas, rich in hydro-carbons, and is generated by bringing calcium carbide in contact with water. It is composed of 92.3 parts by weight of carbon, and 7.7 parts of hydrogen. When mixed with air, in a proportion from 1 to 4 up to 1 to 20, it is very explosive, its explosive force being much stronger than that of coal or water gas. The more the gas is condensed, the more explosive it becomes, and in its liquefied form it is so dangerous that its use is at present everywhere prohibited.

The purity of acetylene gas depends upon the purity of the raw material from which it is made. Calcium carbide always contains phosphorus, sulphur and nitrogen, and unless purified, the resulting acetylene gas will contain phosphoretted hydrogen, sulphuretted hydrogen and ammonia. The improved processes of manufacture of calcium carbide do away with these impurities.

Purified acetylene is not as dangerous to breathe as coal or water gas; it takes also, in burning, less oxygen from the atmosphere, and creates much less carbonic acid in combustion than the ordinary gas. It is, too, of a much higher luminosity than ordinary gas, burns with a white flame, and, owing to its richness in hydro-carbons, special burners with small orifices or jets and burning only half a cubic foot of gas per hour must be used; these give about 25 candle-power light, against 16 candle-power of the ordinary 3 to 6 cubic foot burners. The ammonia contained in acetylene gas will form a chemical explosive combination with copper; hence copper gas fixtures, piping or generators should not be used.

Numerous forms of apparatus for making acetylene gas have been devised. Practically, there are three types of generators:—(*a*) those in which a measured quantity of water is supplied gradually to a large volume of calcium carbide, contained in a closed vessel; (*b*) generators in which the carbide is immersed in water and then withdrawn, the action being repeated from time to time; (*c*) generators arranged so that a measured quantity of carbide is dropped into a large volume of water. The generator and the gasometer may be fitted up separately or together. From the point of view of safety it is advisable to place the generator in a brick vault, outside of a building, the same as with air gas machines.

Owing to the necessary use of very small burners, it will take a much longer time before a room, in which a gas cock is left open, will hold a mixture danger-

ous to health. The odour of acetylene gas being very peculiar and distinct, a small leak is rendered very noticeable. Quite recently a new lighting gas, made from pure acetylene gas by dilution, has been used, as the following newspaper item shows:—

"The first place in the United Kingdom to be illuminated with the bright white light of 'Electroid gas' is Hunmanby, a Yorkshire village near Scarborough. This new illuminant is composed of acetylene with the admixture of inert matter and a proportion of oxygen. Its manufacture is claimed to be of the simplest nature. The gas can be delivered through any ordinary gas main at the ordinary pressure, measured by means of gas meters, and charged for in the same way as is the custom where ordinary coal gas is used. The light is described as perfectly white, and equal to 250 candle-power, as against the average 17 candle-power of coal gas."

According to an article by Dr. Paul Wolff, in a recent issue of *Glaser's Annalen für Gewerbe und Bauwesen*, the town of Schönsee, in West Prussia, is now supplied with acetylene gas from a large plant, designed for 2000 burners.

Gas is, finally, made from oils, melted fat, resin, petroleum, peat, and from wood. Owing to the cost of these materials, only a few oil or wood gas works are in existence. Gas is made from petroleum or from naphtha by decomposing the same in heated retorts. Such gas requires no purification, is very rich in heavy hydro-carbons, but is too expensive to be sold in a commercial way. It is used more as a means to enrich the non-luminous water gas, and to render this less dangerous in use by imparting to it a distinct odour.

The gaseous impurities of ordinary coal gas are sulphuretted hydrogen, vapour of carbon disulphide, carbonic acid and ammonia. These reduce the lighting qualities of the gas, and the sulphuretted hydrogen, in burning, produces sulphurous and sulphuric acids, which are destructive to metallic articles, plants and are injurious in general. Sulphuretted hydrogen can be traced by holding a strip of paper, dipped in sugar of lead, which, in the presence of this impurity, becomes discoloured and turns brown, the intensity of the latter colour being an indication of the degree of impurity.

Carbonic acid can be detected by leading the gas through lime water, which thereby becomes cloudy or white. The presence of ammonia is indicated by dipping a glass rod in muriatic acid and holding it over an open gas burner, when a white fog will form. The purification processes remove all but a small quantity of these gaseous impurities.

While sulphuretted hydrogen is a poisonous ingredient, the quantity contained in well-purified gas is so small that it may be disregarded. From a health point of view, the really dangerous poisonous ingredient of both coal and water gas is the carbonic monoxide. This is present in both kinds of gas, the amount in coal gas being from 7 to 10 per cent., and in carburetted water gas from 25 to 40 per cent. Chemistry teaches that carbon monoxide, or carbonic oxide, is a colourless and tasteless gas, a little lighter than air, which burns with a bluish flame, forming carbonic acid. It acts as a strong poison, producing asphyxia and often death when inhaled in small quantities. Its toxic effect is due to a combination with the haemoglobin of the blood, which is thereby rendered unfit to take up oxygen in the lungs. In coal gas, as well as in carburetted water gas, the carbonic oxide is simply a diluent, the same as marsh gas. It does not appear to be practically possible to remove it from ordinary coal gas, though it is stated that a part of it can be removed from water gas.

As regards danger from explosions, the light carburetted hydrogen, and to some extent the olefiant gas or the heavy carburetted hydrogen, are the dangerous elements, for these, mixed in certain proportion with atmospheric air, form a mixture which explodes when ignited.

When lighting gas was first made, objections were raised against its use, because of the products of illumination,

when the gas was burnt. But nowadays it is a well-established fact that no serious danger to health, beyond the mere contamination of the air, results from the burning of purified illuminating gas. The contamination of the atmosphere can, of course, be counteracted by proper and sufficient ventilation. The products of burning gas are, theoretically, only water and carbonic dioxide.

Unburnt gas, however, is dangerous, no matter how made. Escapes of unburnt gas are, therefore, to be avoided. The dangers are twofold, viz., first, asphyxiation, and second, explosions, the latter sometimes accompanied by fire. The danger of asphyxia is greatest with pure water gas, next comes carburetted water gas, then gas made from wood, coal gas, and finally natural gas. Neither the air gas nor the acetylene contains carbonic oxide, though the breathing of such gas may be injurious for other reasons. The danger of gas explosions, caused by mixtures of gas and common air becoming ignited, is present with all kinds of gas, though the proportions between gas and air, which are explosive, differ somewhat with the different kinds of gas.

Dangerous escapes of gas may occur either at the works where the gas is manufactured, or in the distribution system in the streets, or finally in the houses where the gas is consumed as fuel or as illuminant, or for power purposes. Gas escapes in buildings are either due to leaks, or to carelessness or ignorance in the use of gas, or to accident.

At the gas works, where either coal or water gas or carburetted water gas is manufactured, the workmen are, to some extent, exposed to the danger of explosions due to escaping gas, and, on the other hand, are liable to suffer from breathing gas which may escape from the retorts, the gas holder, or at other points in the works. It is stated on good authority that accidents at gas works from the inhalation of coal or water gas are comparatively rare. Where water gas is manufactured, there is, of course, a greater danger than with coal gas, owing to its large percentage of carbonic oxide. Good ventilation in the gas works is always an essential condition. The workmen are also liable to suffer from exposure to the heat and from sudden changes of temperature. The ammonia of unpurified gas, moreover, attacks the mucuous membrane of the respiratory organs. Besides this, the workmen may suffer from the vapours caused by the extinguishing of the burning coke, and in the purifying department workmen who clean and empty the lime boxes are liable to inflammation of the eyes from the gases and odours.

The gas distribution system embraces the street mains, the house and lamp services and the gas meters. There is always some leakage of gas connected with the distribution mains, the gas escaping either at the joints or from imperfect pipes, or from breaks in the mains. From 7 to 10 per cent. of the daily output is estimated to be lost by leakage from the gas mains. Cases of asphyxiation occur when workmen make connections with the gas mains, or when they go into trenches in which a broken gas main is to be repaired.

The chief danger connected with escapes of gas under the street surface is that the gas will often find its way through the soil and escape into the houses located along the street. When such gas leakages occur, the peculiar pungent odour of the gas is sometimes partly or completely lost by filtration through the soil. Where this is the case, it is much more difficult to detect a leak or break, and the buildings and their occupants along the line of such defective or broken gas main become exposed to two grave dangers, namely, the danger of explosion and of asphyxiation. Many cases are on record of people having become asphyxiated in houses not provided with any gas service. This danger, as was first pointed out years ago by Professor von Pettenkofer, is particularly great in winter time, and this for two reasons:—first, the street surface is apt to be frozen hard and will not permit the gas to escape upwards where it would do no harm and where it might be quickly noticed; then,

again, it is well known that houses in winter time act like chimneys by reason of the temperature inside being higher than that outside. They, therefore, draw in the ground air, as it were, and with it the gas which has leaked into the soil. The dangers are, of course, aggravated by the fact that at night, and in winter particularly so, the doors and windows of bedrooms may be closed. Professor von Pettenkofer relates a great number of instances where not only one person, but sometimes entire families, have been found in the morning asphyxiated by gas which had entered houses in this manner. Sometimes the gas escaping from the main will follow along the line of house sewers and will thus gain entrance to the cellars; in other instances it follows the tubes or conduits which enclose the electric light wires.

Where no asphyxiation occurs, dangerous explosions may happen by reason of the escaping gas mixing with the air. The striking of a match, or the bringing down into the cellar of an open flame will speedily cause this result. Only recently a fatal gas explosion occurred in a residence street in New York City, in a house which had not been occupied for the entire summer, but where a workman had entered in the morning to make some improvements. Five minutes after he was seen to enter the house, an extremely violent explosion occurred, which blew out the entire front and rear walls of the three-story brick and stone building, causing a fire in this and several adjoining houses, resulting in the death of the unfortunate workman. The cause, in this instance, was a broken gas main from which the gas had been escaping into the cellars of the houses along the street for probably many days or weeks.

The danger of being asphyxiated is in all cases much greater where the gas manufactured is the so-called carburetted water gas. Where otherwise healthy persons, living in houses not supplied with gas, awake in the mornings with persistent headaches or nausea, it is always well to bear in mind the possibility of carbonic oxide poisoning from gas escaping in the manner described above. In case of a break of a street gas main, the most important thing to do until the gas company can shut off the gas and reach the leak is to keep open all windows of the cellar and basements, and also to avoid having any open light.

It is difficult to suggest a remedy for the conditions named, except that wherever an escape of gas is noticed in a street it should be immediately reported to the gas company and they should act promptly in the matter, and, if necessary, cut off the gas from the entire street rather than continue to expose the houses to such dangers. A German chemist, Professor Bunte, has suggested a ready method for testing the tightness of gas street mains at intervals of 6 to 10 feet along their line. Small holes, from 12 to 16 inches deep, are bored, and in each opening an iron tube, ½ inch in diameter, is placed, which has within it a glass tube containing a roll of test paper. This paper is dipped into a solution of palladium chloride, and any trace of gas escaping from the main at once acts upon the paper, colouring it a slight brown or even black, according to the extent of the leak. If, on the other hand, after, say, 10 minutes, the paper remains white, it is a safe indication that at the point tested there is no escape of gas.

To the distribution system belong also the house and lamp services and the gas meters. The house services should be laid with the same care as is required for the inside gas piping system, and any leak which shows itself in the cellar at the point where the service enters should be at once repaired by notifying the company to whom the piping belongs. Breaks in services to street lamps are sometimes indicated by the fact that a street lamp suddenly burns very dimly.

The consumers' gas meters, which form the connecting link between the house service and the house pipes for gas, should also be tight and all connections made with the greatest care. Connections with iron pipes and fittings are preferable to those of lead. Acci-

dents sometimes occur to workmen of the gas company when replacing a defective gas meter or cleaning out house services that have become stopped up. In all such cases the greatest care should be observed to avoid asphyxiation.

In piping houses for gas it is always well to bear in mind the dangerous nature of the gas to be carried in the pipes. Of whatever kind the gas may be with which the house is to be lighted, whether natural gas, coal gas, water gas, air gas, or acetylene gas, the piping should be absolutely tight in the joints, and the tightness should always be ascertained by carefully testing the gas piping system after completion. It has been pointed out by scientific investigators that even slight gas leaks in houses, when going on for a long time, will have an ill effect upon the health of the inmates. They will suffer not only from headaches, vertigo and nausea, but also in some cases from sore throats. Quite often such gas leaks and their effects are erroneously attributed to sewer gas. Larger leaks of gas are dangerous, first, by reason of persons becoming asphyxiated, and second, because the gas, when mixed with air and brought in contact with a flame, will cause explosion or a fire. Many accidents are annually recorded where persons have searched for a gas leak with an open light, and even mechanics, who should know better, at times risk their lives by this practice.

In laying out the gas piping system for a building it is of the utmost importance to so arrange the pipes, in size and manner of distribution, as to avoid at any point in the system the possibility of a sudden reduction in the gas pressure, for where this happens a flame which may have been turned down low is liable to go out, and when the pressure is re-established, death by asphyxiation may result through the escape of gas.

It would require too much space to explain in detail how the gas piping of houses should be properly arranged. The writer has, therefore, in an appendix to this paper, given some suggestions which contain practically all rules which it is necessary to follow to have a well-arranged gas piping system and to avoid the escape of gas from a defective house piping system. A few points of caution are here added:—First, in piping a house always keep the gas pipes away from bell wires, for cases are on record where such wires, in constant contact with the gas pipe, have gradually cut the pipe, causing a hidden leak of gas which was often extremely difficult to find. Second, gas pipes should always be kept away from steam and hot water pipes, and also from hot air flues, smoke pipes and from electric light wires.

Where small leaks of gas in the pipes of a house are suspected, a very simple method in detecting these is to watch the small index hand of the gas meter. Whenever this moves, when no lights are burning and no gas is used in the house, there must be, somewhere, a gas escape. Sometimes a gas leak may be noticed by a rumbling sound in the gas meter when all the burners are closed.

In the system of gas fixtures, in which gas is either burned for illumination or else for cooking or heating purposes, there are a number of points which require close attention. First, there is the joint where the fixture is attached to the gas piping or to the gas outlet. Except for the few temporary connections by means of rubber tubing, this joint is nearly always a fixed joint. It, therefore, should be made with the same care as any other joint in the pipe system, but the makers of gas fixtures, who usually attach the latter, are very often guilty of carelessness or bad workmanship.

Next come the fixtures themselves. Of whatever material they are made, the tubing through which the gas is conveyed to the point where it is burnt should be absolutely tight. It would be well if all gas fixtures were tested before leaving the factory, for owing to the fact that the gas keys are seldom absolutely tight, it is a difficult matter to test the gas fixtures in a house after they are once connected.

Third, the gas keys, which govern the flow of gas, are very often found to

be loose in the joint or else worn out, and in that case a constant, though small, escape of gas may result. Keys which turn too hard are equally bad, as accidents may happen by reason of the gas not being entirely shut off. Numerous fixtures have either folding or extension or telescopic joints. All such joints constitute places where an escape of gas may occur. Particular attention should be called to the danger of old-fashioned gas fixtures with so-called "all around" cocks, that is, having keys without stop pins. The writer has held long ago that the use of such fixtures should be prohibited by legislative act. Where the keys are provided with pins, these are often made of too light material and break or snap off. The joints of extension fixtures should be watched with particular care. So-called water-joint pendants are liable to have the water evaporate, and it is best to substitute glycerine for the water. Very often the tubing of chandeliers corrodes or splits and gas leaks result. Where portable table lamps are used, the rubber tubing may become worn out or cracked and permit gas to escape.

All gas keys should be properly greased and loose keys should be tightened to avoid the slightest leak of gas. The joints where the gas burner is attached to the fixture should also be made tight, as it otherwise may leak gas when the latter is turned on.

Accidents may occur from all the causes named. In some published statistics of deaths from gas asphyxiation a few other causes are pointed out, of which the following may be mentioned:—Combination gas and electric light fixtures in which the gas key may be turned on, being mistaken for the electric light key. The use of so-called independent cocks is also somewhat dangerous when the two keys are placed together, one of them controlling the light and the other a connection to a gas stove, as the one may be turned open by accident when the other is closed.

Heating and cooking fixtures must also be connected with care and must not have any leaky places. Where rubber tubing is used for temporary connections, accidents may occur from the tubing slipping off the joint or becoming sufficiently loose to permit an escape of gas.

Where gas pressure regulators are used at the meter these should be carefully examined for tightness, for very often slight leaks are found in such appliances. Each single leak may be ever so small, yet the aggregate of such leaks in a house may lead to a serious contamination of the air and to the bad effects on the health of the occupants due to slow poisoning referred to above.

Numerous accidents occur annually in the use of gas for lighting, cooking or heating, through either carelessness or ignorance. The largest number of accidents, probably, occur from ignorant persons either blowing out the gas or turning it off and subsequently turning the cock on sufficiently for the gas to escape unnoticed. This is particularly liable to happen in hotels and lodging houses, where persons who have never used gas before, take rooms; but it also happens now and then in private families in the bedrooms of servants not acquainted with the use of gas. Fatal accidents usually occur in small rooms having no ventilation, during the sleep of the occupants.

Many other accidents are the result of the bad practice of turning down a gas flame, particularly in a bedroom. This is always ill-advised, for such a turned-down flame may be either blown out by a draught of air from an open window, or else it may be extinguished by a sudden variation or reduction in the pressure. When this happens in a small bedroom without ventilation, there is great danger of asphyxiation, particularly so if water gas is used. Much can be done to avert this danger by a proper arrangement of the gas piping in houses.

Another dangerous custom is to shut off the gas at the main service or at the gas meter during the night, and numerous accidents, some of them fatal, have resulted from it. It is almost equally bad to turn off the gas at the meter during the day.

Notwithstanding the universal intro-

duction of gas lighting, there are still many persons who would be benefited by receiving plain instructions on the use of gas in the household. Gas companies would benefit themselves and the public by paying more attention to this matter. Among available statistics may be found numerous incidents of death or accidents due to faulty management of gas. Among the more remote causes the writer finds the following mentioned:—In one of two adjoining rooms, supplied with gas from one so-called prepayment gas meter, a man retired for the night when the gas supply from the meter was exhausted, but forgot to close his gas burner. The occupant of the adjoining room came home late at night, dropped a coin in the slot of the gas meter and got a fresh supply of gas, which meanwhile also escaped in the adjoining room, killing the occupant.

Escape of gas and explosions have also happened in the use of gas cooking stoves, where boiling water, running over the vessel, extinguished the flame. It has already been mentioned that the so-called independent gas connections with two keys may lead to accidents by the wrong one being turned by mistake. Where the gas in the cellar freezes in winter time, it is dangerous to attempt to thaw out the gas meter or service with a flame. A gas meter should never be examined with a burning light, nor should any tools be used near a gas meter known to be leaky, on account of the danger of flying sparks.

According to the official statistics of the Board of Gas and Electric Light Commissioners of the State of Massachusetts, 105 gas accidents occurred in that commonwealth in the year 1897, causing 60 deaths and 74 injuries. In the year 1898, 101 accidents occurred, causing 77 deaths and 45 injuries. While a portion of these deaths were due to suicidal intent, the majority of cases were accidents which might have been prevented by a stricter inspection of the gas piping and fixtures.

It cannot be overlooked that the danger is a serious one and one that is sure to increase as the use of carburetted water gas becomes more universal. Without a desire to draw comparisons as to the relative dangers from sewer air and from illuminating gas poisoning, the writer has always held the view that both are equally preventable by proper supervision of buildings old and new.

In recent years the supervision of gas piping and gas fittings has been agitated in numerous places, and in some of these the enactment of laws has resulted governing gas piping and the inspection of such work in all new buildings. Among the safeguards to be applied, the writer would mention, first, the enactment of official regulations regarding the arrangement of the gas pipes in buildings and the provision for official municipal inspection and for testing all work in connection with it. It is advisable that all manufacturers of gas fixtures should test their output at the factories. Second, the periodical inspection of gas-lighting fixtures and other gas appliances in hotels, lodging houses and tenements by the municipal authorities. Third, the prohibiting of the use of gas in all sleeping rooms of less than a stated number of cubic feet capacity. Fourth, the use of so-called automatic burners in the sleeping rooms of hotels and lodging houses. The term "automatic" in this connection is intended to designate a gas burner from which gas cannot escape except when lighted. Several ingenious so-called "self-lighting" burners have been patented within a year or two and are now placed on sale. If a person should blow the gas out where these burners are used, the gas will become automatically lighted and no asphyxiation can result. Fifth, it has also been repeatedly suggested to restrict by law the amount of carbonic oxide in gas and to prohibit the distribution of any gas containing more than a stated quantity of this poisonous ingredient. In the writer's judgment, it will be a difficult matter to enforce such a statute, and managers of gas companies may surely be expected to oppose any such measures, as in recent years they found it to their advantage to manufacture a carburetted water gas instead of the coal gas.

Under all circumstances diligent care

should be exercised in the use of gas fixtures and gas fittings. This, together with an official supervision of the gas piping and with popular instructions disseminated by gas companies to their customers, will accomplish much good in preventing fatal accidents in the future.

APPENDIX

SUGGESTIONS FOR THE PROPER ARRANGEMENT OF GAS PIPING WORK

Gas Service.—To be of wrought iron pipe, of ample size; to be run into building with pitch back to street main where possible; or else to be provided with siphon or drip pipe and emptying plug where service must necessarily be graded toward the house. Service pipe to be protected from frost wherever necessarily exposed.

Gas Meter.—To be preferably a dry gas meter; to be of ample size: all connections to be preferably of wrought iron pipe; fittings to be beaded malleable iron fittings; no lead meter connections to be used. Meter to be set in a cool, ventilated, well lighted place, easy of access, but protected from accidental injury.

House Gas Piping.—To be of good quality of wrought iron pipe, preferably galvanised. Steel pipe, being somewhat brittle, is not so good. Lead gas pipes should not be permitted. Cast iron pipe is used only for services larger than 2½ or 3 inches diameter.

Pipe Fittings.—To be of malleable iron, preferably beaded fittings. Fittings to be selected and examined for sand-holes. Galvanised fittings to be preferred.

Joints.—To be screw joints. Use red and white lead mixed, or boiled linseed oil in joints. Use precaution not to get lead on the inside of joints. No gas fitter's cement to be used on joints under any circumstances. The practice of rusting the pipes up by filling them with water is bad and should be prohibited. Unions should be avoided; if required, use ground joint union fittings. No washer joints should be permitted. All joints must be made absolutely tight.

Shut-offs.—Use best quality heavy brass work; round-way ground key lever cocks are preferable to valves, as they indicate at once by position of lever whether the pipe line is open or shut. Valves, if used, should be soft-seat brass valves. Iron valves not to be permitted, as they quickly corrode from the action of the gas.

Hooks, Straps, and Clips.—All pipes to be well fastened by hooks, straps or clips of wrought iron, not of cast iron. Use screws for fastening, no nails or common hooks.

Cutting of Floor Joists.—This should never be done by the gas-fitter; the carpenter to do all cutting, and beams should not be notched, bored or cut more than two inches in depth, and never further away from the wall, or bearing supporting the beams, than two feet.

Sizes of House Pipes.—No pipe to be less than ⅜″, better ½″. In determining sizes of pipes, follow Table I for sizes of house pipes for gas lighting, and Table II for sizes of gas pipes for gas ranges and gas logs. Make all piping ample in size. For acetylene gas the piping may be much smaller than indicated in the table.

Arrangement of Gas Piping.—No risers to be placed in outside walls. No riser to be less than ¾ inch. A number of separate risers is desirable; these should be connected at the top for a better circulation of the gas and to avoid undue variation in the gas pressure. Another method is to have separate risers for each floor. For gas logs in fireplaces run entirely separate risers, one for each vertical group of fireplaces. Provide a separate riser for the gas cooking range in the kitchen. A separate meter for gas used in cooking or heating is also desirable.

Larger risers to be kept exposed in closets; smaller pipes to be tested before being covered up or plastered over. Running lines in floors to be kept accessible by floor boards secured with brass screws instead of nails.

Run all branches for side lights up from below, and do not drop them from above (except in the cellar). Place no

running gas lines under tiled floors or hearths. Supply drop lights from branches taken off from side or top of running lines, never drop the branch from the bottom of a line. All horizontal gas pipes to be run with sufficient fall back to the riser; the horizontal run at cellar ceiling to have a fall towards the gas meter. All long horizontal runs between floor beams to be well supported to avoid sagging and traps. Avoid all condensation of gas in pockets or depressions.

Gas Outlets.—Place no gas outlets behind doors or too near window trim or curtains.

Test of Gas Piping.—The entire gas piping, when completed and before plastering is begun, to be tested by gas-fitter with air pump and mercury gauge (22″ long); spring gauges are not reliable. Test the piping under a pressure equivalent to a column of mercury in gauge 18 inches high (9 pounds). Mercury in gauge must stand one hour without indicating a greater fall than ¼ inch per hour. All leaks and defects which the test reveals to be made good by gas-fitter. No split pipe or broken fitting, or fitting having sand-holes, to be repaired with cement or solder.

In large buildings test gas piping in sections. After the test, have a number of capped outlets opened slowly, on each of the floors, to make sure by the falling of the mercury in the gauge that the entire piping has been under the test, and that no parts are accidentally or intentionally disconnected. After test leave all outlets capped tightly. When alterations in the gas are made or additional lights are put in, test the altered work in the same manner as in the first test. Before the gas fixtures are hung or put up, the gas-fitter to repeat the test in the presence of the contractor for the gas fixtures, so as to demonstrate to him the tightness of the entire piping. This leaves the fixture man responsible for any leaks discovered when the gas is first turned on at fixtures. After fixtures are hung, apply another pressure test with 3 inches of mercury in gauge.

TABLE I

Sizes of gas pipes, maximum lengths and maximum number of burners (at 6 cub. ft. each):

	Max. Length	Max. No. Lights
⅜-inch pipe	20	2
½ " "	30	3
¾ " "	40	6
1 " "	60	10
1¼ " "	70	15
1½ " "	100	30
2 " "	150	60

TABLE II

Sizes of gas pipes for gas logs and cooking ranges:

	Max. Length	Sufficient for
½-inch pipe	100 ft.	1 cooking burner or 1 gas log
¾ " "	100 "	2 " " 2 " "
1 " "	100 "	Gas cooking stoves with 4 burners or 4 gas logs
1¼ " "	100 "	Larger gas ranges or 7 gas logs

Gas logs and burners of cooking ranges are assumed to have a consumption not exceeding 35 cubic feet per hour. For a larger consumption, increase the size of pipe supplying log or range.

THIRD-RAIL CONDUCTORS FOR ELECTRIC RAILWAYS

By Leo Daft

A VIEW ON THE BALTIMORE ELECTRIC RAILWAY IN 1885, SHOWING AN EARLY FORM OF ELECTRIC LOCOMOTIVE

THE use of a third-rail system of supplying current to electric railway motors naturally suggested itself to the early electric workers as the most simple and direct means at hand, especially as a large quantity of old rails generally figured as a more or less important asset of those roads whereon the eager experimenter was grudgingly permitted to spend his money, and incidentally that of his friends, in showing how he thought it ought to be done. The third-rail line placed on the Saratoga and Mount McGregor steam railroad, in the United States, in 1883, consisted of a 35-pound ordinary section rail, mounted on wooden blocks which had been baked and plunged in boiling pitch while hot from the baking. The foot of the rail was further protected by a thin rubber cushion turned up over the flanges and spiked in place, with an iron guard under the spike head to prevent cutting. With a pressure of less than 150 volts the leakage, even in wet weather, was insignificant.

The first attempt at bonding was by thoroughly cleaning the joint plates and bearing surfaces and bolting up tightly with thin, tinned copper plates interposed; but this proving unsatisfactory, a supplementary ground wire was connected to each joint by taking a turn of the wire between tinned iron washers under the bolt heads. In this way the

resistance was reduced to a working quantity, and with the outer rails similarly treated, a fairly good conductive system was obtained. No guards were considered necessary, as the line was an ordinary steam road and the public was warned off the right of way; but while operating with a potential of only 130 volts, several horses were thrown down at surface crossings, involving a compliance with a demand for substantial fenders at those points, which was urged by horse owners with some emphasis.

In equipping the Baltimore and Hampden branch of the Baltimore Union Passenger Railroad, in 1885, the local conditions were different, as the conducting rail ran for its entire length of something over two miles on one side of the public road. Considerable opposition having been encountered from residents along the right of way, the local council made a promise to guard the whole of the third rail an indispensable condition of granting the needful permit. After a few more skirmishes with bucolic malcontents, a quantity of antediluvian rail of about 35-pound section was exhumed from somewhere and kindly tendered as suitable for conducting purposes. No alternative appearing, the rails were laid on cast iron hoods, of the now familiar umbrella form, supported on turned wooden blocks, treated as were those at Saratoga, and with the flaring foot driven into the dove-tailed groove of a cast iron shoe. Fig. 1 is a sectional elevation of this insulator. The bonding was similar to much that has been in use until quite recently, the webs of the rail having been bored by hand drills and connected by a heavy copper wire by means of tinned copper rivets, previously attached to the wire

THE GUARD RAILS FOR THE CENTRAL CONDUCTOR

by soldering. The surface of the rails was so thickly covered and pitted with rust that, after a short struggle, all

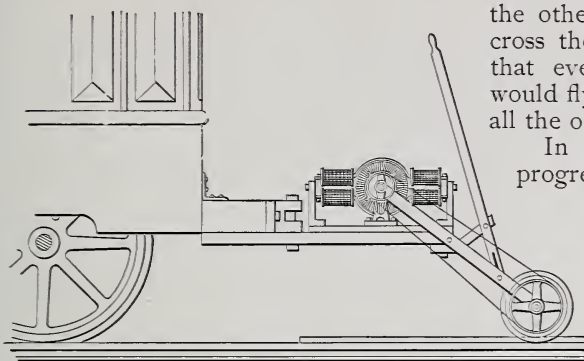


FIG. 2.—A RAIL CLEANING DEVICE

efforts to clean it by hand were abandoned, and the writer devised a method of applying a power-driven emery-wheel by mounting an electric motor on the front platform of one of the electric cars. The wheel was mounted on a rocking frame and was driven by belt from a pulley on the armature shaft; the arrangement is clearly shown in Fig. 2. Current was taken from the motor leads, and the car was run slowly back and forth while the emery-wheel was quickly turned and pressed downward by the hand lever; in this way the two miles of conductor were soon made clean and bright.

The rail thus prepared remained in constant use for four years, or until September, 1889, and during that time over 1,250,000 paying passengers were carried over it. The illustration on page 235 is from a photograph showing the arrangement of guard rails at turnouts, with two trains passing, and the views on pages 236, 238 and 239 show the guard rail at curves and gradients. Before the

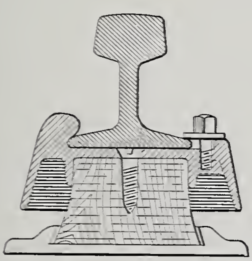


FIG. 1

guard was placed, some leaders of a flock of geese, accustomed to feed in neighbouring meadows, received shocks while having one foot on the rail with the other to earth in attempting to cross the line, with the singular result that ever afterward the whole flock would fly over not only these rails, but all the others in the neighbourhood.

In 1885, while work was yet in progress at Baltimore, the writer equipped about two miles of the Ninth Avenue Elevated Railway, in New York City, with a 60-pound third-rail, supported on insulators of much higher resistance than any hitherto made for railway work. These were of the umbrella form previously used, but instead of wooden supports, a vulcanised fibre or hard-rubber sleeve was firmly forced into the

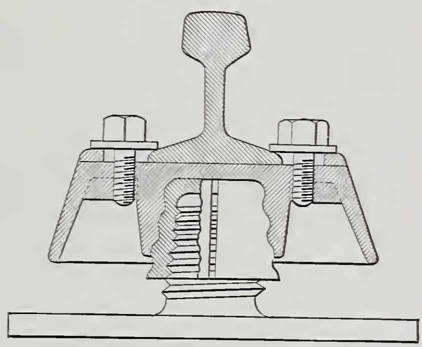


FIG. 3

umbrella socket by screwing the tapered and threaded standard of a cast iron chair into the cavity. Fig. 3 is a sectional elevation of this insulator. A few tests quickly exposed the unfitness of fibre for out-door insulation, on account of its pronounced hygroscopic qualities, and after discarding it in favour of a special kind of hard rubber the insulation was found to be relatively high in any weather.

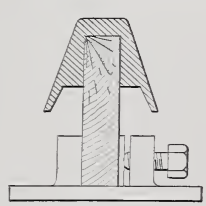
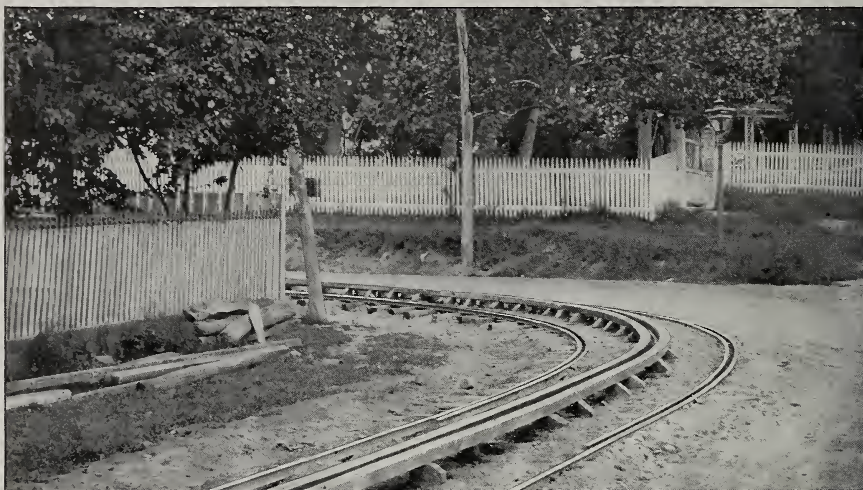


FIG. 4

With a view to avoiding the use of expensive insulators, the writer, in December, 1884, devised a special rail section which is shown in Fig. 4, and conductive purposes; on the contrary, it is usually too high for convenient installation where large cross-section is needed; especially is this true where, as



ROUNDING A CURVE ON THE BALTIMORE ROAD

was intended for service on the New York elevated railway and at Baltimore; but the expense of rolling a new section precluded its use at that time, and it has only recently been adopted on the Nantasket Beach line of the New in the United States, ordinary locomotive pilots have to be taken into account. Fig. 5 is a special section with the web and head expanded to meet cases of this kind. The insulator here shown is an almost exact copy of one used by the

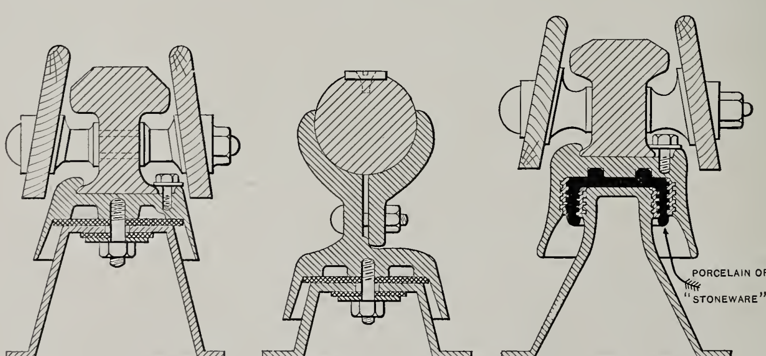


FIG. 5 FIG. 6 FIG. 7

RAIL CONDUCTOR AND INSULATOR SECTIONS

York, New Haven & Hartford Railway. With the exception of facilities for making a mechanically strong joint, the standard section of rail offers no advantage for writer in 1888 to support a round iron bar conductor, 4 inches in diameter, on a short section of the Ninth Avenue elevated railway at New York. The bar was

fitted with a countersunk bronze contact rail, attached by means of screws at frequent intervals, and as the expansion coefficient of the two metals differed but slightly, no trouble was found on that score. Fig. 6 is a sectional view of this type. This conductor is electrically equal to a standard section of about 135 pounds per yard, including the bronze contact rail. A carefully made insulator of this kind has much to recommend it, since it is very strong mechanically, and by the use of gaskets and sleeves of good micacious compound or suitably prepared asbestos, the insulation is ample for potentials not exceeding 600 volts on live sections of only a few miles long.

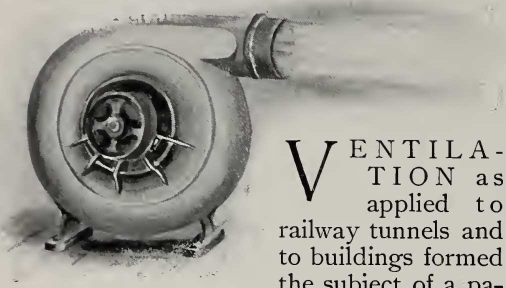
Unless some really practical method of local transformation shall be evolved, suitable for heavy and fast service, it seems probable that higher potentials will be used between sub-stations on long trunk lines worked with polyphase currents, in which case insulation should receive more serious attention than has been deemed necessary, not only from motives of economy,—for a constant leak of only a few ampères will cost more in most cases than the interest on a through system of insulation, —but also because leakage means a gradual and sure breakdown of barriers. For a proposed installation where a potential of 750 volts was contemplated, the writer designed a track insulator in 1897, which is shown in Fig. 7. It will be seen that the umbrella is cored for serrated sides to correspond with the chair head, and between them a strong, cup-like insulator of porcelain, "stoneware" or like material, is firmly locked in place by a lead-antimony alloy, containing a trace of copper, which slightly expands in cooling. Experiment has demonstrated that, with reasonable care in the making, this insulator has great mechanical strength and an electrical resistance comparable with the highest in use for any purpose. Cements of various kinds have been used in making up insulators, but a properly proportioned metallic alloy is better out of all proportion to its increased cost, since it has much greater mechanical resistance and will not disintegrate and fall out under constant shocks and vibration,—a fault common to all cements.

Should the present high price of steel rule for some time to come, it seems not unreasonable to anticipate a large use of aluminium either for third-rail or surface feeding purposes.

ANOTHER VIEW OF CAR AND LOCOMOTIVE

THE VENTILATION OF TUNNELS AND BUILDINGS

By Francis Fox, M. Inst. C. E.



VENTILATION as applied to railway tunnels and to buildings formed the subject of a paper recently presented by the author to the Institution of Civil Engineers, of Great Britain. The principle there stated, and hitherto acted upon where mechanical ventilation has been adopted for tunnels, has been to exhaust the vitiated air at a point midway between the portals by means of a shaft with which is connected a ventilating fan of suitable power and dimensions. In the case of the tunnel under the River Mersey, such a shaft could not be provided, owing to the river being overhead, but a ventilating heading was driven from the middle of the river (at which point entry into the tunnel was effected) to each shore, where a fan, 40 feet in diameter, was placed. By these means the vitiated air is drawn from the lowest point of the railway, and fresh air flows in at the stations on each side, to replenish the partial vacuum. In the Severn Tunnel, owing to the middle of its length being nearly at the Gloucestershire side of the river, a vertical shaft is sunk to the tunnel, and a fan, 45 feet in diameter, extracts the vitiated air at this point.

Objection has been taken to this system of placing fans midway between the entrances of a tunnel, as being liable to be affected by a strong wind blowing in at either end. There is some ground for this contention, but the late Mr. Hayter stated to the recent Departmental Committee of the British Board of Trade that the only difference he observed was that the speed of the air travelling to the fan was about 1 mile per hour less in one direction than in the other. It may also be noticed that when a strong wind is blowing into a tunnel, no artificial ventilation is required, and the fan may be stopped with advantage. It is when the air in the tunnel is stagnant, or is moving very slowly, that mechanical aid is required, and a fan of suitable size and power effectually accomplishes the result desired. The author has, by inquiry and by personal experience, ascertained that if the amount of carbon dioxide can be kept low, so as not to exceed 20 parts in 10,000, the air in a tunnel is satisfactory.

The consumption of coal by a locomotive during the passage through a tunnel having been ascertained, allowing 29 cubic feet of poisonous gas for each pound of coal consumed, the volume of fresh air required to maintain the atmosphere of the tunnel at the above-mentioned standard of purity is ascertained as follows:—The number of pounds of fuel consumed per mile, multiplied by 29, multiplied by 500, and divided by the number of minutes' interval between the trains, will give the volume of air in cubic feet which must be introduced into the tunnel per minute to maintain it in a sufficiently pure state to avoid inconvenience.

As an illustration, assume that the tunnel is one mile in length, and the consumption of fuel is 32 pounds per mile, and that one train passes through the tunnel every 5 minutes in each direction; then the volume of air required per minute will be:—

$$\frac{32 \text{ pounds} \times 29 \text{ cubic feet} \times 500}{2\frac{1}{2} \text{ minutes}}$$

$= 185{,}600$ cubic feet; and the air will

then be maintained at a standard of purity in which the carbon dioxide does not exceed 20 parts in 10,000.

This is the basis upon which the Mersey and the Severn Tunnels are ventilated, and which have been shown to be efficiently supplied with fresh air; it is, however, to be regretted that, in the case of the Mersey Tunnel, owing to the impecuniosity of the company, inferior coal is now used, and the fans are driven at a lower speed than was intended. The airways then become encrusted with soot, which in some places is between 2 inches and 3 inches in depth; but, notwithstanding these drawbacks, the examination of the air of the tunnel, made by Dr. John Haldane, F. R. S., for the Departmental Committee, showed that the amount of carbon dioxide was considerably less than 20 parts in 10,000. There is no doubt that this tunnel, when proper coal is used and the fans are run at the intended speed, is the most perfectly ventilated tunnel of its kind in the world.

The Mont Cenis Tunnel is about 8¼ miles in length and 26 feet in width, and, in consequence of the mountain above it, possesses no shaft. The construction is of excellent character, the tunnel being lined throughout with masonry or brickwork, except two lengths of 330 feet and 260 feet, respectively. In these two lengths solid white quartz was encountered, which occupied years to penetrate. Owing to an alteration during construction, on the Italian side, the Bardonecchia entrance is at a considerably lower level than that originally intended, necessitating the introduction of an ascending gradient of 1 in 40 for a length of about 1000 yards from the portal. The tunnel is then nearly level for about 3½ miles, when a descending gradient of about 1 in 40 occurs for nearly four miles towards the French side. The higher altitude of the middle of the tunnel above its entrances has compromised its ventilation, and sometimes great difficulty is experienced in carrying on the traffic.

At the Bardonecchia entrance there is a somewhat obsolete installation of seven overshot water-wheels, 5 metres in diameter, and 6 metres in length on the breast, over which in succession a mountain stream is conducted. These wheels work air-compressors, the air being delivered under a pressure between 4½ and 6 atmospheres, and discharged at points 1 kilometre apart throughout the tunnel. The quantity of air is so small that for purposes of tunnel ventilation it has little effect, amounting only to 70 cubic metres per minute of air at 75 pounds pressure per square inch; but it is of great advantage to the men employed in the tunnel. At intervals of 1 kilometre there are refuges for the men, supplied with fresh air, water and a telephone. Into these chambers the men can retire when the smoke is thick, and there wait for an engine to take them out.

The corrosion of rails is very rapid, and, were proper ventilation provided, it would not only be of the greatest comfort to the men, but the life of rails would probably be doubled. About 300 tons of rails have to be relaid every year, so that, were their life doubled, a saving of 150 tons would be effected annually, which would probably far more than pay for efficient ventilation. The author is informed that a preservative against rust is now being used, but with what result he is not aware. The temperature of the middle of the tunnel remains nearly constant during summer and winter, and is about 66° to 68° F.

The St. Gothard Tunnel is 9⅓ miles in length, and 26 feet in width; it is nearly level from end to end, the gradient being only that needed for drainage purposes. The ventilation was entirely natural until recently; but, owing to the use of briquette fuel, with its dense smoke, and to the constant increase of the traffic, a time arrived when it was necessary that something should be done, and recently the Saccardo system has been adopted.

In long tunnels on steep gradients, such as exist in Italy and elsewhere, artificial ventilation is imperatively needed. In the cases of the Pracchia Tunnel, 3000 yards in length on a gradient of 1 in 40; the Mont Cenis Tunnel, with its peculiar longitudinal sec-

tion, described above, with gradients of 1 in 40 at both ends; the spiral tunnels, with gradients of 1 in 40, on the St. Gothard route, and the long tunnel of Ponte Decimo, near Genoa,—grave inconvenience and even worse results arise. Asphyxiation is not unknown, and the loss of life attending the collision of August 11, 1898, at the mouth of the last-named tunnel, in which twelve persons were killed and forty injured, was the direct result of bad air.

The case of the Pracchia Tunnel is interesting. It is one of fifty-two tunnels on the main line between Florence and Bologna, built by the late Mr. Thomas Brassey, Assoc. Inst. C. E. These are single-line tunnels, on a gradient of 1 in 40. The traffic has increased greatly and has to be worked by heavy locomotives. Under any condition of wind the state of this tunnel, about 3000 yards in length, is bad; but, when the wind is blowing in at the lower end at the same time as a heavy goods or passenger train is ascending the gradient, an almost insupportable state of affairs is produced. The engines, which are working with the regulators full open, often emit a large quantity both of smoke and steam, which travels concurrently with the train. The locomotives weigh 55 tons, without tender. They have eight wheels coupled, with a tractive force of 15,400 pounds. The goods trains carry 250 tons of load, and have an engine in front and one at the rear; and when, from the humidity in the tunnels, due to the steam, the wheels slip and possibly the train stops, the condition of the air is indescribable. A heavy train with two engines, conveying a Royal party and their suite, arrived on one occasion at the upper exit of the Pracchia Tunnel with both engine men and both firemen insensible; and on another occasion, when a heavy passenger train came to a stop in the tunnel, all the occupants were seriously affected.

The Saccardo system of ventilation has just been applied to the Pracchia Tunnel with remarkable results. Mr. Marco Saccardo, the well-known Italian engineer, avails himself of the annular space between the interior surface of the tunnel and the gauge of maximum construction, and, upon the principle of the injector, blows, by means of a fan, a large volume of air into the tunnel at its mouth. This induces a strong inward current at the central opening, through which the trains pass. The author measured the volume and temperature of air with the following result. Before starting the fan, the tunnel was filled with dense smoke from end to end, the temperature being 107° F., with 97 degrees of moisture, or nearly complete saturation. With the fan running, the thermometer indicated 80° (the temperature of the external air), or a fall of 27°, the moisture was normal, and the amount of air propelled by the fan was 164,000 cubic feet per minute, that by the induced current being 46,000 cubic feet, making a total of 210,000 cubic feet of air per minute passing through the tunnel. The air is blown in at the upper end, and down the incline, the object being that an ascending train with its heavy trail of smoke and steam may be freed at the earliest possible moment from the products of combustion. These results are remarkable, and the air of the tunnel is cool and fresh. This system, however, cannot be applied to railways in which underground stations exist, as the effect of the current would be to blow the smoke to the platforms of the next station, the very part of the railway which should be kept in the best condition.

The Simplon Tunnel, now under construction, will be 12¼ miles in length, and will consist of two parallel tunnels, at a distance of about 50 feet apart from centre to centre. The gradient from Brigue is only 1 in 500, and this for drainage purposes for a distance of 6¼ miles; thence the rails will fall on a gradient of 1 in 142 for the remaining 6 miles to the Italian portal. The ventilation of this tunnel has been very carefully considered, and although it is not definitely decided which system is to be adopted, it is not improbable that the Saccardo system will be selected, as in those cases where shafts are not available it is the only one that can be ad-

vantageously employed. Even where shafts exist, and there are not intermediate stations, it is probably the most effective and economical method.

In the near future it is not improbable that the traffic in many tunnels, with frequent train service, will be worked electrically, in which cases the problem will be greatly simplified. The author desires to call particular attention to the need which exists in many tunnels during construction of a sufficient and even bountiful supply of fresh air to the workmen. With it they work with far greater comfort and vigour; without it the work progresses much less rapidly, at greater cost to both the company and the contractor, and with lasting injury to the men.

As regards work under compressed air, attention has been on several occasions directed to the still greater need of ample air beyond the air-lock, to secure immunity from the various symptoms ordinarily developed by compressed-air work.

The ventilation of buildings usually falls within the province of architects, but the matter has not hitherto been efficiently dealt with in practice, and is of such importance that the author desires to submit a few remarks upon it.

To allow sewer-gas to enter a house is now an indictable offence, and the owner of premises who fails to take steps to prevent it soon finds himself before the magistrate. Legislative measures ought to be taken to prevent any public building, hall, church or house from being used, unless a sufficient quantity of pure fresh air is introduced with regularity. The importance of keeping houses clean, streets swept and sewers flushed, is admitted,—all with the object of maintaining the air in a pure condition; and after millions have been spent with this aim in view, air is allowed to become absolutely foul and putrid for want of proper ventilation. Air which has passed through the human lungs has been well designated "air-sewage" and is highly poisonous. It is then breathed, re-breathed, and breathed again to the injury of all present, and with the result of the serious illness and the death of some.

The condition of public assembly-rooms cries loudly for amelioration. Coughs, colds, sore throats, bronchitis, neuralgia, headaches, dyspepsia, and many other maladies are, in many cases, directly attributable to vitiated air; and as a recent writer says, in reply to an objection that open windows allow smuts to enter, "Smuts may be bad, but they are as white as snow compared with impure air."

The condition of the air in houses often results in the rooms becoming dangerous to the health of their occupants. It has been stated by an eminent authority on consumption,—Dr. Ransome, F. R. S.,—that seventy thousand deaths occur annually in Great Britain from tuberculous diseases, nearly all of which could be avoided were the subject of fresh air both understood and acted upon by the community. Were such a loss of life to occur in battle or by shipwreck people would stand aghast; but this vast multitude are allowed to drop into their graves with hardly a protest or an effort to save them. Were proper precautions taken, these diseases would soon become as rare as the formerly prevailing disease of leprosy. The French require in many of their hospitals 50 cubic feet of fresh air per minute to be supplied to every patient. The author considers that if 20 cubic feet per minute, which, however, is a low standard, can be secured for each person, the air will be maintained in a sufficiently pure condition for ordinary purposes. Allowance must also be made for any gas-lights in a room. Each ordinary burner consuming 5 cubic feet of gas per hour vitiates the air nearly to the same extent as would five persons, the rule being that each cubic foot of gas burned is equivalent to one person.

The late Dr. Thomas Carnelly, in a report on "The Air of Schools," gives the following table:—

Method of Heating.	Number of Rooms Examined.	Cubic Space per Person.	CO_2 in Volumes per 10,000	Micro-Organisms per Litre of Air.
1. Mechanical ventilation	32	160	12.3	18.5
2. Hot pipes and natural ventilation	43	176	16.3	78.0
3. Open fires and natural ventilation	84	145	19.2	158.0

This conclusively points to the great advantage of mechanical ventilation.

Carnelly, Haldane and Anderson suggest that 13 volumes of carbonic acid in 10,000 should be regarded as the maximum allowable impurity in school air; and, in a paper published by the Royal Society on the "Air of Sewers," it is stated that this air has been found to be in a very much better condition than that of naturally ventilated schools, and to contain a much smaller number of micro-organisms than any class of house. The following table illustrates this:—

Place.	Temperature.	Volumes of CO_2 in 10,000.	Volumes of Oxygen to Oxidise the Organic Matter in 1,000,000 Volumes of Air.	Micro-Organisms per Litre of Air.
	°F			
In sewers	54.0	7.5	7.2	8.9
Outside air at same time	49.0	3.7	2.2	15.9
In houses—				
One-roomed	55.0	11.2	15.7	60.0
Two-roomed	53.5	9.9	10.1	46.0
Four-roomed and upwards	54.5	7.7	4.5	9.0
In schools—				
Naturally ventilated	55.6	18.6	16.2	152.0
Mechanically ventilated	62.0	12.3	10.1	16.5

In the case of all large buildings three main points have to be considered: – (1) the area of floor to be provided for each person; (2) the cubic capacity of the room required for each occupant; and (3) the number of cubic feet of air per minute which must be brought in, and then extracted, for each individual. Nos. 1 and 2 will depend upon the objects to which the room is devoted, whether a ward of a hospital, or a school, or a place of public assembly; and there are numerous text-books on hygiene which will afford sufficient guidance in such cases. As to No. 3 there is great diversity of opinion, but no great harm will occur to an audience occupying the room for a comparatively short time, if 20 cubic feet of air per minute are provided. The United States Book on School Architecture gives a practical application to its remarks on this subject as follows:—

"The amount of fresh air which is allowed to hospital patients is about 2500 cubic feet each per hour. Criminals in French prisons have to content themselves with 1500 cubic feet per hour. Assuming that we care two-thirds as much for the health of our children as we do for that of our thieves and murderers, we will make them an allowance of 1000 cubic feet each per hour, or about 16 cubic feet per minute. Forty-eight children will then need an hourly supply of 48,000 cubic feet. Definite provision must, therefore, be made for withdrawing this quantity of foul air. No matter how many inlets there may be, the fresh air will enter only as fast as the foul escapes, and this can find an outlet only through ducts intended for that purpose, porous walls and crevices serving in cool weather only for inward flow. What, then, must be the size of the shaft to exhaust 48,000 cubic feet per hour? In a shaft 20 feet high, vertical and smooth inside, with a difference in temperature of 20°, the velocity will be about 2½ feet per second, or 9000 feet per hour; that is, it will carry off 9000 cubic feet of air per hour for every square foot of its sectional area. To convey 48,000 cubic feet, it must have a sectional area of 5½ square feet."

The author does not, in giving the amount of fresh air to be supplied, desire that this should be regarded as by any means absolutely satisfactory, but only an improvement upon the present state of things. He is aware that the standard of purity suggested is low, and ought to be exceeded; but he fears that it might deter many from moving in the matter if a proper and higher standard were to be laid down at first. He also desires to point out that one of the most important points to be aimed at is the proper warming of the fresh air introduced into buildings; if this be not done, the first step that is taken when

a cold day occurs is to have all the ventilating arrangement closed. The fact should not be lost sight of that the air in a room may be quite cold and yet very foul; whilst, on the other hand, it may be warm and yet perfectly fresh. To avoid draught, the air should enter through a large number of small orifices, so as to thoroughly diffuse the currents. This is done by gratings, but the effect of these gratings is to very seriously diminish the volume of air passing through, owing to friction of the bars. The same remark applies to extracting-flues. Owing to the small size and the roughness of the surface, the velocity of the upward current is small, and it often results in the quantity of air passing through being much less than is requisite.

The author is of the opinion that no large building can be successfully ventilated without some mechanical force furnished by steam, electricity, falling water or some such agency. Fans can then be worked with assured results, whereas automatic extractors not infrequently become inlets, thus reversing the whole system and pouring cold air on the heads of the audience. As regards the plenum system, whatever its merits and its success may be, means should also be provided by the introduction of open windows to aërate when required the whole building in sections; and these should be so arranged that no corner can be left stagnant or unswept by the purifying current. Nothing can take the place of this free circulation, and to be able to take advantage of this in suitable weather is most desirable. The extraction of foul air should be effected at the top of a room or building, so as to utilise the natural tendency of warm air to rise. The inlets should be about five feet above the floor. In the case of one of the American legislatures, the warmed fresh air is allowed to enter on the level and in front of the desk of each member, so that he secures a proper portion of fresh air before it is breathed by his neighbour.

As regards private dwellings, improvement must be sought in the education of the public to the value and merits of fresh air. Many, if not a majority of, persons seem to regard air as a somewhat questionable gift, and look upon night air as absolutely poisonous, to be excluded from their rooms at all cost. The simplest method is to keep the window slightly open at both top and bottom, so as, in fact, to provide an "up-cast" and "down-cast" current. If this be found to be obnoxious, let a window board, 6 inches deep, be placed under the sash; this keeps an opening at the meeting rail, which, in conjunction with the chimney flue, will prevent asphyxiation.

THE HONOURABLE CHARLES ALGERNON PARSONS

A BIOGRAPHICAL SKETCH

ONE of the distinct achievements in steam engineering during the latter part of the nineteenth century has been the commercial development of the steam turbine and its application to useful purposes on a comparatively large scale. With this work the name of Charles Algernon Parsons has become inseparably associated, and the Parsons steam turbine has by this time secured a degree of recognition which, less than twenty years ago, would have appeared wholly chimerical.

Born in 1854 at London, the fourth surviving son of the late Earl of Rosse, of Birr Castle, Parsonstown, Ireland, well known as the builder of the telescope which bears his name, Mr. Parsons, after private tuition at home, entered St. Johns College, Cambridge. In 1874 he became a scholar of St. Johns, and in 1876 graduated eleventh wrangler. It was at college that the idea first came to him that the reciprocating engine was not destined to be the engine of the future, and that the ideal engine must be purely rotating and without reciprocating parts.

In 1877 Mr. Parsons entered the works of Lord Armstrong, as an apprentice, and served with them until 1881, when he joined Messrs. Kitson, of Leeds, remaining with them until 1883. In 1884 he became a partner in the firm of Messrs. Clarke, Chapman & Co., Ltd., of Gateshead-on-Tyne, the name of the firm becoming Messrs. Clarke, Chapman, Parsons & Co. The electrical industry at that time being the latest development of engineering, Mr. Parsons conceived the idea that a high-speed, direct-coupled engine was required to drive the dynamo and that the steam turbine was the engine to do it. This was the impetus which was required, and very shortly the first working steam turbine and dynamo was built, the results in the way of low steam consumption, small size and continuous running showing that the steam turbine was at last to begin to take the place of the reciprocating engine.

Although Mr. Parsons was not actually the first to see the advantage which a rotary engine would have over a reciprocating one, yet his turbine was, from the first, the only one which was practical, and it is due to his untiring energy and perseverance that his invention has at last been recognised as one of the greatest inventions of the century. In 1889 Mr. Parsons severed his connection with Messrs. Clarke, Chapman & Co., Ltd., and started the Heaton Works at Newcastle-on-Tyne, devoting his entire energy to the improvement of the turbine.

It is unnecessary here to enumerate the various changes which the turbine has undergone from the first small one of about 5 H. P., which was shown at the Inventions Exhibition, some years ago, down to those of 1000 K. W. each which are now being turned out. The most recent success of the turbine in its application to the propulsion of ships will be fresh in every one's mind, the *Turbinia* having attained the unprecedented speed of 34½ knots at the British naval review at Spithead in 1897.

The two torpedo-boat destroyers which have been engined by the Parsons

THE "TURBINIA" STEAMING AT 35 KNOTS. LENGTH, 100 FEET. BEAM, 9 FEET. DISPLACEMENT, 44½ TONS. THE ENGINES CONSIST OF THREE COMPOUND STEAM TURBINES, EACH DRIVING ONE SHAFT CARRYING THREE PROPELLERS, MAKING NINE IN ALL

Marine Steam Turbine Company, Ltd., of Wallsend, and which are now undergoing their preliminary trials, are expected to steam still faster and to easily attain their guaranteed speed of 35 knots. The application of the turbine to larger boats will follow, and we may expect soon to see Atlantic liners doing 23 to 26 knots as easily as they now do their 20 knots.

Among other inventions to which Mr. Parsons has turned his attention is that of the flying machine; but, up to the present, time has not permitted him to make extended experiments in this direction. A small flying machine was made by him about ten years ago and was probably one of the first examples of a steam engine of extremely light weight, able to lift itself in the air by means of a screw propeller, or, when mounted on aeroplanes, of propelling itself for considerable distances. The weight of the engine, boiler and fins was only 1¼ pounds, and the power developed, ¼ horse-power.

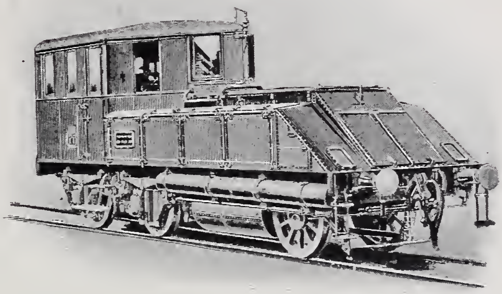
Mr. Parsons is managing director of the Newcastle and District Electric Lighting Company and of the Parsons Marine Steam Turbine Company, Ltd., at Wallsend, and also director of the Cambridge and Scarborough Electric Supply companies. He is a Fellow of the Royal Society, president of the Institute of Junior Engineers, and a member of the institutions of Civil Engineers and Electrical Engineers of Great Britain.

Current Topics

It is an unfortunate truth that the benefits which might be derived from many a good contrivance are frequently brought to naught through the neglect of details of installation which by themselves may seem comparatively unimportant and yet are the controlling factors in the problems into which they enter. A very good illustration of this was encountered recently in the boiler room of a large manufacturing establishment, in which, with progressive spirit, mechanical stokers had been introduced. Strangely enough, however, as it seemed at first, the firemen did not appreciate the innovation, but went on firing in the good old-fashioned way without evoking comment until, one day, a chance visitor's inquiry why this was so developed the simple fact that, with the stokers in use, the men were compelled to shovel the coal into fuel hoppers at an inconvenient height above the floor level, entailing more effort than was required to throw the coal through the furnace doors lower down. This, with the men,

sealed the doom of their mechanical assistants. The stokers, without the needed adjustments of overhead coal bins and possibly necessary coal conveying and elevating machinery, in this instance represented just so much waste investment and might have been profitably sold as scrap.

One of the latest locomotive oddities has taken shape in a design worked out under the supervision of Messrs. Baudry and Auvert, of the Paris, Lyons & Mediterranean Railway, in France. It is an electric storage battery locomotive, modelled substantially after the pattern shown in the annexed illustration, and has been in trial service on one of the branch lines running out of Paris. According to what particulars have been given of the machine, the main driving current is supplied from batteries carried on a separate tender. The engine itself has three axles, two of which are driving axles, and have armatures mounted directly upon them. The housing of the locomotive is built in five distinct compartments. The one in the rear, which is situated directly above the motors, is the cab for the motorman and his assistant. A central forward compartment of moderate height, so as not to obstruct the view of the motorman, contains an air compressor run by a small electric motor. This apparatus furnishes the compressed air necessary for the operation of the air brakes and whistle. Of the three other compartments, two are situated on the right and one on the left-hand side of the engine. Each of the former contains nine cells of accumulators, which, connected in series, are used to excite the fields of the motors and furnish the current necessary for the compressed air and the lighting. They can also run the locomotive at a very slow speed. The fifth compartment contains a large water rheostat which opens and closes the circuits of the motor fields and also regulates their intensity. The current for the locomotive is furnished by two batteries of accumulators of 96 cells each, which are carried upon the previously mentioned tender. Of the results of the trials which have been made with the locomotive and of the particular advantages which it is supposed to possess for possibly special service we



A FRENCH STORAGE BATTERY LOCOMOTIVE

are told practically nothing. All things considered, the thought readily suggests itself that the design represents simply another addition to the already long list of locomotive freaks.

How much room still remains in China for the exercise of educational effort was illustrated recently in an interesting manner by Lord Charles Beresford in an address before the Institution of Mechanical Engineers. Lord Beresford, almost fresh from a Chinese tour of inspection which had for its immediate object the study of possible British trade extension in the Far East, had enjoyed exceptional opportunities for collecting experiences, and one of these was the following:—In the arsenal at Shanghai he happened to notice a Krupp gun fitted with an Armstrong breech-piece. He was told that this had been rendered necessary because the Chinese had blown off the original breech-piece, and on going to a fort upon the river, in charge of a Mandarin, he found out how the accident happened. They were using for the 67-ton guns a powder which was

quite unsuitable, and he said:—" That powder will blow the breech-piece off." The Mandarin nodded, smiled, and answered, " Yes, it does." The last time the gun was fired, he said, it killed fourteen men; so then they loaded another gun and fired it, and that time twenty-four men were killed. These guns must have cost in mounting and breeching at least £50,000. In another place there was a battery of five 60-ton muzzle-loading guns. He asked where the front of the battery was. The Mandarin pointed in one direction, but the guns pointed in another. On this being mentioned to him, the Mandarin replied:—" Yes, I think there has been a mistake." The guns were arranged in echelon, so that the men working one gun would have infallibly been killed by the discharge of the next. He demonstrated this to the Mandarin, who replied:—" Yes, some men would no doubt be killed, but the shot would reach the enemy." At another place he found that the gun was actually loaded in the magazine, and he said:—" If there were any carelessness in sponging the gun after firing, the magazine would be blown up." The Mandarin in charge gave him a slap on the back, and replied:—" You are one of the cleverest men I have ever met. The year before last we did fire these guns, and we blew up the magazine just as you have said. I will show you where it was." The Mandarin added that he did not remember how many men were killed, but he believed that it was fifty.

For nearly three years the famous little torpedo-boat *Turbinia*,—the first vessel fitted with steam turbine machinery,—has held the distinction of being the fastest vessel in the world, and not a little interest is attached to the photographic reproduction elsewhere in this issue showing her while steaming at what may truly be called the now marvellous speed of 35 knots, or a little over 40 miles an hour. The *Turbinia* was commenced in 1894. and, after many alterations and preliminary trials, was satisfactorily completed in the spring of 1897. It may be worth noting anew here that her principal dimensions are, length, 100 feet; beam, 9 feet; and draught of water under the propellers, 5 feet, the trial displacement having been 44½ tons. Steam is furnished by a water-tube boiler with 1100 square feet of heating surface and 42 square feet of grate area, and closed stokeholds are used, with the air supplied by a centrifugal fan mounted on a prolongation of the low-pressure turbine shaft. The engines consist of three compound steam turbines, high-pressure, intermediate and low-pressure, each driving one screw shaft; on each of the shafts are three propellers, making nine in all; the condenser is of the usual type, and has 4000 square feet of surface. When officially tested, she attained a mean speed on the measured mile of 32¾ knots, and the consumption of steam for all purposes was computed to be 14½ pounds per I. H. P. of the main engines. Subsequently, after some small alterations to the steam pipe, she was further pressed, and during some of these later trials the phenomenal 35-knot speed was reached.

The first vessels of larger size than the *Turbinia* to be fitted with steam turbine machinery are the torpedo-boat destroyer *Viper* for the British Government, and a similar vessel for Sir W. G. Armstrong, Whitworth & Co., Ltd. These vessels are of approximately the same dimensions as the 30-knot destroyers now in the British service, but have slightly more displacement. The boilers are about 12 per cent. larger, and it is estimated that upwards of 10,000 horse-power will be realised under the usual conditions, as against 6500 with reciprocating engines. The engines of these vessels are in duplicate. Two screw shafts are placed on each side of the vessel, driven respectively by a high and a low-pressure turbine, and to each of the low-pressure turbine shafts a small reversing turbine is permanently coupled for going astern, the

estimated speed astern being 15½ knots and ahead 35 knots. Two propellers are placed on each shaft. The latter of the two vessels mentioned has already reached a speed of upwards of 32 knots. The manipulation of the engines is a comparatively simple matter, as to reverse it is only necessary to close one valve and open another, and as there are no dead centres, small graduations of speed can be easily made.

A COMPARATIVELY new field of usefulness for traction engines has come with the war in South Africa and a number of British firms have latterly been busy, day and night, turning them out for that seat of operations. Exactly what they will be expected to do there it has evidently not been found expedient to make public, though it is only natural to infer that they will be put to transport service, hauling stores, and possibly even guns, and generally supplementing the work of the railway, which may be broken up at any time. During the Franco-German war in the early seventies traction engines were used for probably the first time in military service, but the conditions of operation were measurably different on that occasion, and it is safe to say that nothing even remotely approaching Transvaal transportation obstacles was encountered. Of the trials which were carried out a short time ago with the first completed lot of the South African engines previous to their shipment, *The Engineer*, of London, says that these took place in the Long Valley at Aldershot, and while the broad rivers and the huge stone boulders of the Transvaal were lacking, there were ravines, and sand, and mud in plenty to test the staying powers of the machines, which, it should be added, came out with flying colours. Some of them were sent across country, and managed to keep up a speed of six miles an hour or more, passing on the way over ditches, hills, and watercourses. Many of the ditches had water in them, and the banks were steep. Sometimes the engines were nearly up to their hubs in mud, but they all came through. Others had to traverse deep gullies, which they managed to do. The utility of the crane jib, which sometimes forms part of the equipment of engines of this type, was amply demonstrated. There was no difficulty in removing from a train of trucks one which was supposed to be injured. The engine simply went and lifted it out of the way. Then it was shown how that one engine might haul another engine with its train out of a bad place by means of a steel rope, should they stick and remain fast. In fact, they were given the hardest tasks to perform which the military authorities could devise, and they successfully carried them out. The largest of the engines weigh some 15 tons, they can draw from 30 to 40 tons, will carry water enough for a seventeen miles' run without stopping, and will travel thirty to forty miles a day. They will be provided with coal trucks, and a sort of a living-van for the use of the engineers in charge.

FOR years traction engines have been at work quietly in the colonies of Great Britain, doing what is very similar to that which will be required of them in the Transvaal. Take Australia and New Zealand, for example! There, far up-country and away from all possible lines of communication with the outside world, are numberless farms. If these produce nothing else, they at all events rear sheep. Before the advent of the traction engine the wool had to be laboriously carted down to the nearest railway station or the nearest port, in waggons drawn by bullocks. Now, however, in a large number of instances, traction engines with trains of trucks visit these farms regularly, and it is said that it is by no means unusual to find an engine having behind it a load of wool worth some £1500 or £1600. In places the roads are of the most primitive kind, and bridges of any size are wanting. Most likely, if they existed, they would not carry the weight of a traction engine. Fords there are,

however, and the traction engines go through these just as a bullock waggon would. The fires, of course, are frequently put out; in fact, it is not unusual to have the top of the railing round the driving platform under water. Curiously enough, this immersion does not appear to do any serious damage. Traction engines are said to have worked for years under these conditions, and are still at work. Hill-climbing power, too, under bad conditions is possessed by them to a marked degree, so that, altogether, the engines have a list of qualifications which ought to enable them to give good account of themselves in the work for which they are intended in South Africa.

Along with the traction engine in the South African campaign we find also once more the armoured railway train, which periodically has bobbed up in wars of the past quarter of a century. With each new appearance, however, it has come in a more highly developed shape, and the sand-bag protected locomotive and cars of the earlier days have given way to an iron and steel armoured movable fortress with all the essential

AN ARMOURED TRAIN FOR THE TRANSVAAL WAR

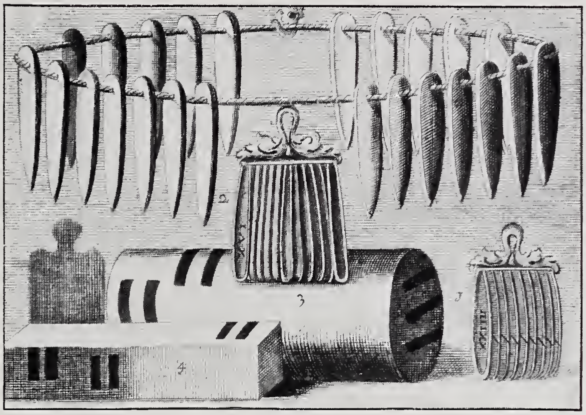
elements for effective offensive warfare. During the recent insurrection struggle in the island of Cuba the Spanish government had two armoured locomotives in service, both heavily plated with steel and equipped for rifle as well as machine gun fire. Against a well-armed foe, however, they were not likely, so far as appearances went, to acquit themselves as well as the armoured train recently sent from Durban to the front to operate against the Boers. A general impression of this may be gained from the little sketch above, which shows what appears to be a pretty thoroughly protected outfit. The steel sides of these are over six feet high, and are loopholed for rifle use. Each car is capable of carrying about 65 men. The engine driver and fireman are completely closed in and take their directions by bell signals.

Apropos of the genesis of the automobile, it is stated in the *Automobile Magazine* that the idea of a vehicle moved by an unseen power is as old as the hills. Among the Egyptian sculptures on the banks of the Lower Nile is a relief representing a royal chariot ascending to heaven, borne upon clouds. In Greek and Roman art, too, there are representations of mystic chariots drawn by invisible coursers. These were efforts of the imagination, like the fancy which pictures sea-shells or rose-leaf carriages, drawn by butterflies, swans, or cupids; but they are, nevertheless, indications of what must be regarded as a conscious straining for higher ideals of locomotion. The first actual appearance of self-propelled vehicles was in Persia, in the day of Alexander the Great, when his phalanx had to sustain the onslaught of tremendous cars, armed with projecting spears and scythes, which his Persian foes rolled down the steep sides of the mountain-passes crossed by his army. These are the contrivances mentioned by Roger Bacon in a treatise on the secret forces of nature, entitled:—"Epistola Fratris Rogerii Baconis de secretis operibus artis et naturæ et de nullitate magiæ." There he says:—"With the aid of science and art alone it is possible to make waggons roll in a fixed direction without the help of draught animals, as did the battle-cars of the ancients with their formidable wheels, armed with scythes and sickles." Similar contrivances were the redoubtable sickle-waggons of the Swiss mountain peasants, which they used in their

battles against the feudal knights of Austria, early in the Middle Ages. If we are to believe the chronicles of the fifteenth century, the onslaught of these waggons, thundering down the mountain-side, propelled only by their own weight, proved overwhelming to the Austrian nobles. In 1649 Johann Hantsch, of Nuremberg, astonished the thrifty burghers of that town by his invention of a carriage which was run by clock-work, and could be made to attain a speed of three leagues an hour. This machine achieved a great reputation throughout Germany, and was finally sold to Prince Charles Augustus, of Sweden, for three hundred thalers. From Nuremberg, too, came the invention of the wheel-chair for paralytics, not long afterward, which, in a modified form, is still in use among invalids, and in 1660 an issue of the *Mercure de France* contained some comments on those carriages, or moving chairs, circulating in the streets of Paris, which were moved by a hidden mechanism, suggesting some trick of the devil, by the marvellous manner of their locomotion.

Now that we have become fairly accustomed to such things as liquid air and liquid carbonic acid, and the charm of novelty is beginning to wear off, Professor Dewar comes forward with the announcement that he has succeeded in solidifying hydrogen, obtaining thereby a temperature of only a dozen or so degrees above the absolute zero. The melting temperature of solid hydrogen he is said to have found as 16 degrees, and by evaporating it he obtained a temperature a few degrees lower. Solid hydrogen, we are further told, seems to be a transparent ice and not a metal as has been heretofore generally supposed, thus apparently upsetting a long established and cherished theory of chemists.

For the assayer of the present day the little sketch shown on this page has a peculiar interest. It was reproduced from the old volume of Pettus on "Metals," and represents a set of touch-needles and touch-stones of the



ANCIENT GOLDSMITHS' TOUCH-NEEDLES

kind used long years ago for determining the degree of fineness of any particular object of gold. The illustration practically tells its own story. Each of the several needles represented a special and known degree of fineness, and a mark, made with it upon the touch-stone, served as a standard for comparison with another mark made by the sample of gold to be tested. The approximation probably was close enough, and the outfit evidently served its purpose well.

The effect of the use of machinery upon cost of production and the relative productive power of hand and machine labour have, by authorisation of the United States Congress, been made the subject of extended investigation on the part of the Commissioner of Labour, and the results of this, which have just been made known, are admirably suggestive of the great debt which the world owes to inventive genius. According to the original Congressional resolution, the Commissioner of Labour was requested to ascertain the effect of

machines operated by women and children upon rates of wages, and also as to whether changes in the cost of production are due to a lack or to surplus of labour, or to the use of labour-saving machinery. In his report the commissioner points out that statistics can give no direct answer to questions of this class, and confines his effort to showing what machines have done to reduce the cost of production. In reviewing the report somewhat at length, *Engineering News*, in a recent issue, says that the terms "hand" and "machine" production are referred to as not being used in their strict sense, since hand operations enter to some extent into even the most modern systems of manufacture, while all hand production, on the other hand, in even the crudest arts, is aided by the use of tools, which are, strictly speaking, machines. The investigation is classified under the heads of agriculture, manufactures, mining and transportation, but the bulk of the work is devoted to manufactures. The saving of time in agriculture, however, is hardly less marked than in manufacturing operations. Thus, to produce and harvest an acre of corn by the methods in use in the fifties is shown to have required 182⅔ hours of labour, as compared with 27 hours when the work is done by the machinery of the present day. An acre of wheat required 64 hours' labour in 1830, as against only three hours' labour in 1896. To harvest an acre of hay required 21 hours' labour in 1850, and only four hours' labour in 1895.

Turning to manufactures, a comparison is made of the old wooden mould-board plough compared with the modern iron plough. To produce one of the old-fashioned ploughs required no less than 118 hours of labour, while the modern plough costs only 3¾ hours. In the brick-making industry hand work amounted to 20 hours per thousand, as compared with 7½ hours by machine. About the same proportionate saving was made in the manufacture of paving brick and of sewer pipe.

In the textile industries, nine-wire body Brussels carpet was woven on hand looms in 1850, with a labour expenditure of 4.04 hours per yard. The same carpet is now woven on power looms, with only a half hour of labour per yard. Cotton sheeting was made from the raw cotton by hand in 1860 with 5605 hours of labour per 500 yards. In 1897 a modern cotton mill turned out the same goods with only 52¾ hours of labour. A large part of the labour consumed in the modern process is chargeable to hand manipulations still in use. Taking up the different operations involved in the production, the most remarkable contrast is found in the carding. Here the ratio of the carding machine to the hand cards was 4140 to 1. In other words, it would require a man 1,980½ hours, or nearly eight months, working 10 hours per day, to card the cotton for 500 yards of gingham, while with machines he could do the same work in 28.7 minutes. In spinning, the ratio in favour of the machine was about 200 to 1; in reeling it was 350 to 1; in weaving it varied in different mills from 11 to 1 to 30 to 1.

In the manufactures of iron and steel, it appears that files are now made with about one-third the hours of labour that were employed by hand workmen in 1872. A rifle barrel took 98 hours' time of a hand workman in 1857, while now it is made with 3⅔ hours of labour. Half-inch bolts, 6 inches long, with nuts, are made by hand at the rate of 500 in 43 hours, while by machinery the same product is turned out with only eight hours' labour. In the manufacture of iron pipe, 100 feet of 4-inch lap welded pipe cost 84⅓ hours of labour in 1835, while the same product was turned out with less than five hours' labour in 1895.

In lumber manufacture, the old-time method was to saw the logs into boards with whip saws, a method still practised in some remote and inaccessible regions.

To saw 100,000 feet of white pine boards by this method in 1854 took no less than 16,000 hours of work. A modern sawmill turns out an equal product with a labour expenditure of but 273 hours. In 1813 iron cut nails were made by hand, with a labour expenditure about 130 times as great as that required to produce an equal quantity of cut nails in a modern factory. In quarrying, the modern compressed air drill can put down thirty holes, 18 inches deep and 2½ inches diameter, in granite rock, with 14 hours, 50 minutes of labour. The same task would require 89 hours' labour with hand drilling. These are only a few illustrations selected from the large number of industries covered in the report; but they help to convey some idea of how much labour-saving machinery has done for the civilised world during the past half century.

It has been asserted that, given a mineral deposit that will adequately repay for the working, no matter where it happens to be situated, the mining engineer will suggest a means of reaching it and bringing it within the sphere of practical utility. From time to time confirmations of the truth of this assertion come to hand, and the gold fields of the Witwatersrand, in the Transvaal, at the present time are furnishing an example. It is only quite recently that the mining world was astonished to hear that some shafts had attained the exceptional depth of 4000 feet, and it was concluded that at 5000 feet the limit for practical purposes would be reached; now, however, with various improvements, particularly in ropes, a depth of 6000 feet has been attained, and winding engines have been installed to do this wind in one stage in a minute and a half. In the Mining and Metallurgical Section of the Engineering Conference of the Institution of Civil Engineers held last year, mention was made of the possibilities of working gold mines to a depth of 10,000 feet in the Transvaal, with a vertical shaft, working to a depth of 6000 feet by a surface installation, whilst the other 4000 feet would be sunk and worked by another installation underground. More recently the matter has been brought to the attention of the South African Association of Engineers by Mr. John Yates, who contemplates with equanimity third and fourth deeps, that is to say, mines at a depth from 5000 feet to 9000 feet, and from 9000 feet to 12,000 feet. The latter is the limit fixed by conditions of temperature, which, on the very liberal allowance of 203 feet to 1 deg. Fahr., are calculated to be unbearable at the latter depth.

Concerning mining operations in China, Consul Smithers, of Chuogking, in a recent report, outlines the methods practised, and the results to which they lead, in the following remarks, which present a queer picture to Western eyes:—The usual manner of getting ore in Yunnan has been to follow a lode from the surface into the ground as long as possible, without going to the expense of sinking a shaft or driving profitless tunnels. The miners have usually been left to do as they pleased under ground, as the government officials and private capitalists have considered it beneath their dignity to explore the caverns dug at their expense or under their orders. The miners, in most instances, have been very badly treated, both by official overseers and private capitalists, and have taken their revenge on their employers by deceiving them to such an extent as to ruin them. Their mode of operation in this respect has usually been to expend all the available capital in getting very poor ore,—in some cases no ore at all,—and leaving columns of the best-paying ore standing in various parts of the underground working, easily accessible whenever it was desired. In this manner, the miners have almost invariably succeeded in exhausting the resources, as well as the patience of the officials and capitalists, with the result that they have been forced to abandon the mines as unprofitable investments, and the miners were disbanded and driven away without pay.

After enduring suffering quietly for a time, the miners managed to repay themselves for their former trouble by extracting in a quiet way the ore they had left in the mines and selling it to petty local manufacturers or themselves coining money, sometimes of weight and quality superior to the legal government issue.

It is not often that jet pumps are used on anything more than a very moderate scale, so that what has been accomplished with one of them of exceptional size at the famous Comstock mines in Nevada, U. S. A., is worth special notice. According to the particulars given in a little pamphlet devoted to the installation, the working of the deeper levels of the Comstock mines was abandoned about a dozen years ago, not owing to any poverty in the ore, but to the great practical difficulties that were encountered in working in depths which, in the case of one shaft, attained 330 feet. The rise of temperature was so great that few miners could stand the work, and over and above this an enormous inflow of water necessitated a heavy expenditure on pumping. For these reasons it was decided to confine all operations to the higher levels, and the mine was allowed to fill up with water, which it did to the 1600-foot level. About two years ago, however, it was decided to re-open these lower levels, the introduction of electric means of transmitting power rendering available for pumping, excellent water powers at no extraordinary distance from the mines. Tenders were invited accordingly for the work, but, contrary to expectations, the lowest tenderer did not propose to adopt electrical methods of working, but to use instead a simple jet pump. The mouth of the shaft from which the water was to be raised lies at an elevation of 6105 feet, and its extreme depth was 2900 feet. A plentiful supply of water was available, and thus the work presented no special difficulty. The supply pipe to the jet in the plant laid down is 12 inches in diameter, and the discharge pipe is 15 inches in diameter. The first pumping station was fixed at 1740 feet below the shaft mouth, and 100 feet below the standing level of the water. The discharge pipe was led into the Sutro Tunnel at a point 140 feet above the level of the jet. The hydraulic head at the bottom of the supply pipe was equivalent to a pressure of 1136 pounds per square inch. The arrangement is stated to have proved both effective and economical, the discharge after the water level had been lowered 100 feet being 3300 gallons per minute, about 3 gallons of water being raised for every one entering the supply pipe. A second jet pump has since been installed.

Apropos of a recently proposed electrolytic method of re-sharpening old files, we are reminded of the statement once made that, after all, the best thing to do with an old file is to throw it away and buy a new one. This has been the conclusion arrived at by a great many whose experience has extended over the once much-talked-of sand-blast file sharpening process and the methods of etching and re-cutting, all of which have been practised with more or less success. Sand-blasting files has been claimed by some to be quite useless, as it makes the teeth shorter and simply raises an edge which has no durability. In re-cutting, the temper must be drawn, and the quality of steel used for files, or at least some of them, has been stated to be such that it deteriorates rapidly when re-hardened. Right here, however, the point may be made, as, indeed, it has been by the advocates of re-cutting, that it all depends upon what grade of file one buys in the beginning. True economy ought to commence by purchasing that file which will yield the largest return for the outlay, and with this grade of file re-cutting has been claimed to pay. The grade which will not stand re-cutting is the cheap, common kind, and buying this has been characterised as a waste of money at the outset. Whether, with the best kind of file that money can procure, etching, too, is an economical sharpening process, remains yet to be definitely decided.

SIR BENJAMIN BAKER, K. C. M. G., LL. D., F. R. S.

THE DESIGNER OF THE FORTH BRIDGE

SEE PAGE 350

Cassier's Magazine

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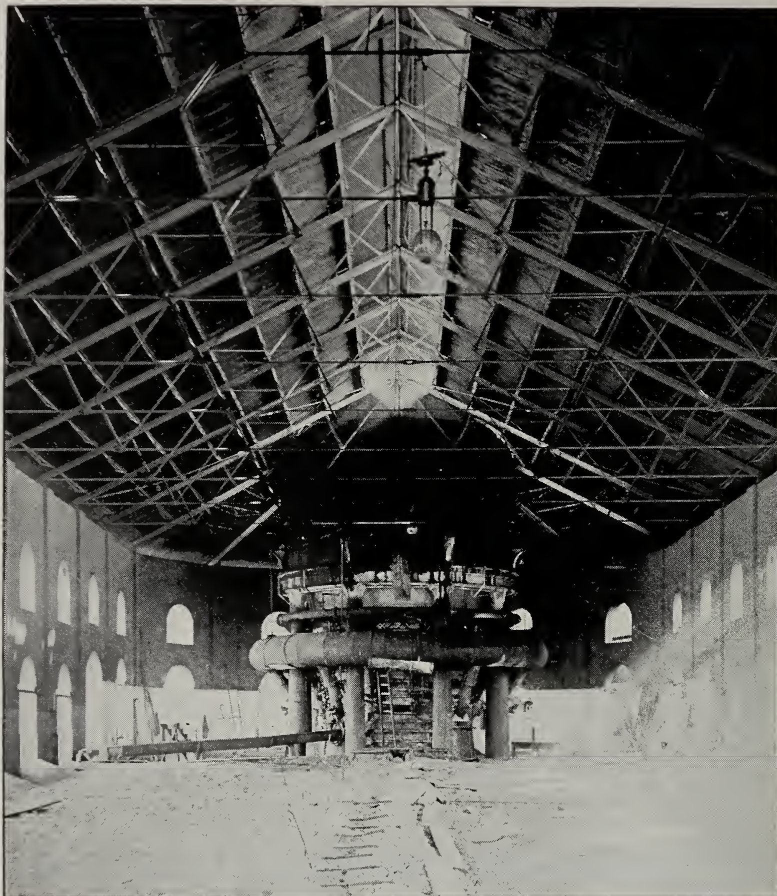
THE MANUFACTURE OF STRUCTURAL STEEL IN THE UNITED STATES.

By F. H. Kindl, C. E.

IT is quite impossible to review in the scope of this article, the successive steps in the evolution of the art of steel making, or to go into the technical details pertaining to steel works practice. The author will, therefore, touch only upon such points as are of direct interest in a general review of the industry. Generally speaking, we find to-day, in the markets, iron in two classes,—pig iron and steel. Pig iron, when melted and cast into moulds of suitable forms, is called cast iron. Cast iron, subsequently treated in ovens by means of oxidising agents, forms what is known as malleable iron. Pig iron contains many foreign substances, and therefore can be formed only in the molten state. It is not ductile, and can be easily broken by means of sharp blows or shocks. Steel, on the other hand, although being only highly purified pig iron, is soft and ductile when heated to a certain temperature, and even to some extent when cold, and can, by mechanical means, be readily shaped to any form.

This great difference in the properties of the two metals considered is mainly due to the percentage of carbon which

SOME OF THE BLAST FURNACES OF THE ILLINOIS STEEL COMPANY, SOUTH CHICAGO, ILLINOIS



IN A BLAST FURNACE CASTING HOUSE.

they contain, either as a mechanical mixture in the form of graphite, or chemically in the form of carbide of iron. As the percentage of carbon increases, the ductility diminishes; but the greater the amount of carbon, the more readily the metal is melted; hence pig iron is preferable for foundry practice.

There are two main classes of pig iron, the gray and the white, the gray having a predominant quantity of graphitic carbon, while in the white combined carbon predominates. The two classifications are again divided into grades which were formerly determined by fracture, but are now estimated by chemical analyses. In the manufacture of pig iron it is quite impossible to avoid the absorption of other elements than carbon by the fluid iron,—such as may be contained in the ore, limestone, and coke which are used in making up the charges. Thus we find in all pig iron more or less manganese, silicon, phosphorus and sulphur. Manganese, as a whole, possesses rather a favourable influence, while the actions of silicon are not of so much consequence. The former plays an important rôle in the production of pig iron, as it increases the fluidity of the slag; it has also a tendency to promote the formation of combined carbon, and to decrease the separation of graphite. Silicon stands contrary to manganese, as it assists the separation of graphite, and is, therefore, useful in the manufacture of soft iron,

where a minimum quantity of carbon is desired.

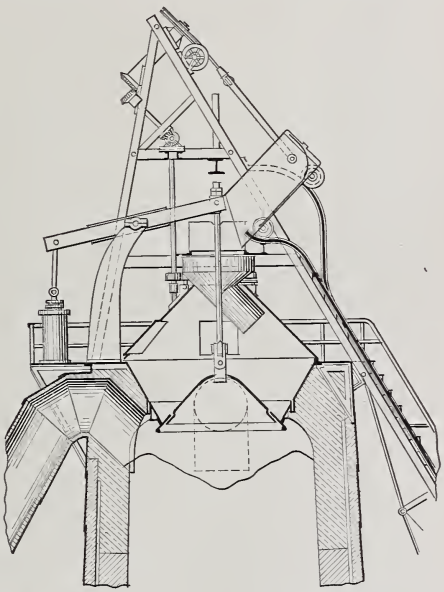
Other elements frequently found in pig iron are nickel, cobalt, and copper. They have but insignificant effects upon its properties, as they are generally found only in traces. Wolfram, tungsten, aluminium, chromium, and even arsenic are frequently added to molten iron or steel in order to give them certain properties.

Pig iron intended for the manufacture of structural steel is produced by the use of coke as a fuel and reducing agent. That produced by the use of charcoal is called charcoal pig; that made by means of anthracite coal is called anthracite pig. Both of these latter grades are manufactured to a very limited extent at present. Very frequently we hear of Bessemer pig iron and basic pig iron, these terms indicating the purpose for which these grades are to be used. Bessemer pig, belonging to the gray iron class, has a very high percentage of silicon, 1 per cent. or more, and is obtained by a high temperature in the furnace. Basic pig belongs to the white iron class, called Thomas iron on the continent of Europe, and contains from 1.50 per cent. to 2.25 per cent. of phosphorus, from 1.50 per cent. to 2.00 per cent. of manganese, and not over 0.6 per cent. of silicon.

Ferro-silicon is a pig iron containing more than 6 per cent. of silicon, and runs commercially up as high as 18 per cent. of silicon. Spiegel iron (so called from the German "Spiegel," meaning mirror) derives its name from the numerous mirror-like reflecting surfaces which it shows in the fracture. It is an iron containing from 6 per cent. to 20 per cent. of manganese, with about 5 per cent. of carbon; commercially it runs nearly 20 per cent. manganese. Its fracture is sometimes snowy white, which runs into rainbow tints with an increasing percentage of manganese. It is hard and brittle, and is used in the manufacture of steel.

Ferro-manganese (iron manganese) is an iron containing from 20 per cent. to 90 per cent. of manganese, and from 5.5 per cent. to 7 per cent. of carbon. Commercially it runs 80 per cent. of manganese. Its fracture is yellowish white, frequently covered with rainbow tints. It is extremely hard and brittle, and irregular in fracture. It is also used in the manufacture of steel, to which it is added to reduce such iron oxides as may have been formed, as well as to recarbonise the metal while still in its molten state. Pig-iron, ferro-silicon, spiegel iron and ferro-manganese are produced in vertical shaft furnaces, called blast furnaces.

The furnaces employed in the various classes of metallurgy are essentially of two types:—first, those in which the fuel is brought in direct contact with the substance to be operated on; and, second, those in which the flame only is employed. Both may be assisted by means of an artificial blast of air.



A BLAST FURNACE TOP, SHOWING CHARGING APPARATUS, STOCK DISTRIBUTOR, ETC.

The blast furnace belongs to the class in which the fuel is in direct contact with the substance acted upon, and on this account it may be considered a somewhat primitive design of heating furnace; but the facts show that no other design can give such economical results, nor are the operations which the ore

ELECTRIC APPLIANCES FOR HANDLING BEAMS AT THE WORKS OF THE CARNEGIE STEEL COMPANY, LTD., PITTSBURGH

undergoes in it in any way simple. On the contrary, a variety of actions constantly take place.

In working a blast furnace, the materials, consisting of iron ore, fuel and fluxes, after being weighed, are automatically hoisted and charged into it at the top or tunnel head, generally through a stock distributor, bell and hopper arrangement, which is used to close the furnace for the withdrawal of the gases without igniting them. The hot blast enters by means of the tuyeres, inserted near the base of the furnace, which are connected with pipes leading from the hot blast stoves, and a zone of intense temperature is created in the region of the tuyeres.

In its passage with the charge down through the furnace, the ore is first exposed to the reducing action of the carbon monoxide, to which it gives off its oxygen, forming carbonic acid gas, as well as taking up some of the carbon from other carbon compounds that may have been formed. The strongly basic calcium oxide of the limestone now unites with the silicious acid of the ore, and forms, in conjunction with the other earthy matter of the ore, a fusible slag. The free and carbonised molten iron is melted in the white hot zone, and drops down to the hearth, collecting in the crucible,—the portion of the blast furnace which is under the tuyeres,—from where it is tapped from time to time and cast into moulds. The slag, being lighter, floats on the top of the molten iron and protects it from oxidation.

Steel plants having furnaces in close proximity do not cast the molten pig iron into moulds, but run it into ladles mounted on cars, which pour their contents into large vessels known as mixers, where several heats of the furnace are gathered, thus insuring a uniform mixture, ready to be delivered to the converter or open hearth furnace, and thus save the re-heating of the pig iron.

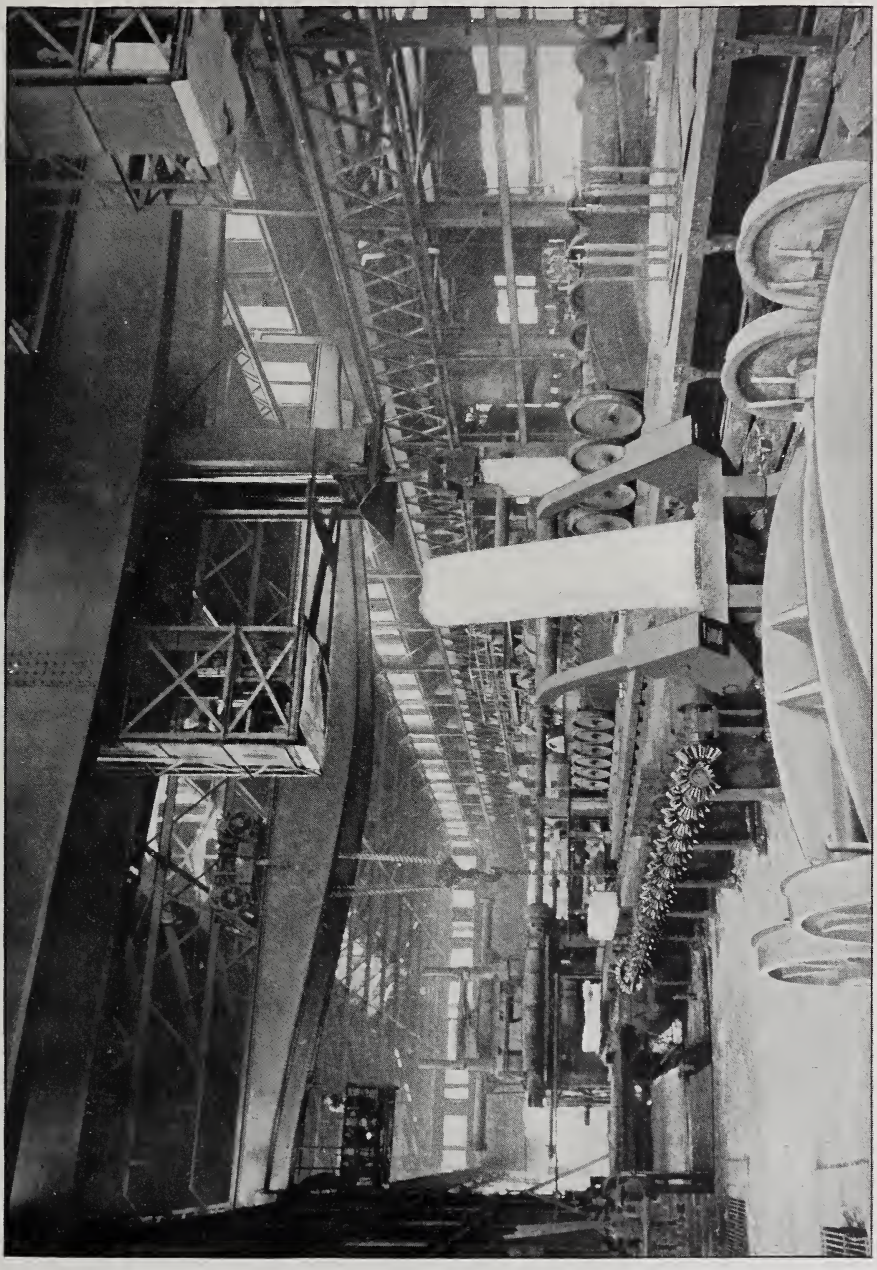
Furnaces are of various capacities, the tendency being toward an increase. While 200 tons of pig iron per day was considered an enormous output fifteen years ago, there are to-day furnaces producing as high as 600 tons. Blast furnaces are run throughout the year, day in and day out, with no exception, until they need re-lining. Re-lining may, in some cases, not be required for several years, while in others furnaces must be re-lined within a year, depending on circumstances. After the re-lining of a furnace, the interior, or brick work, must be most carefully dried before blowing in or starting. The drying should be accomplished gradually and extend over from two to four weeks, depending on the season of the year.

In the immediate neighbourhood of the furnace are the cast house, directly in front, in fact, and other necessary installations for its operation, such as hot blast stoves for heating the air and blowing engines and pumping installations to furnish the necessary air supply and water for the furnaces. Large stock yards and bins, in which are stored immense quantities of ore, coke and limestone, are also close by, from which these materials are taken, weighed, and directly delivered to the furnaces.

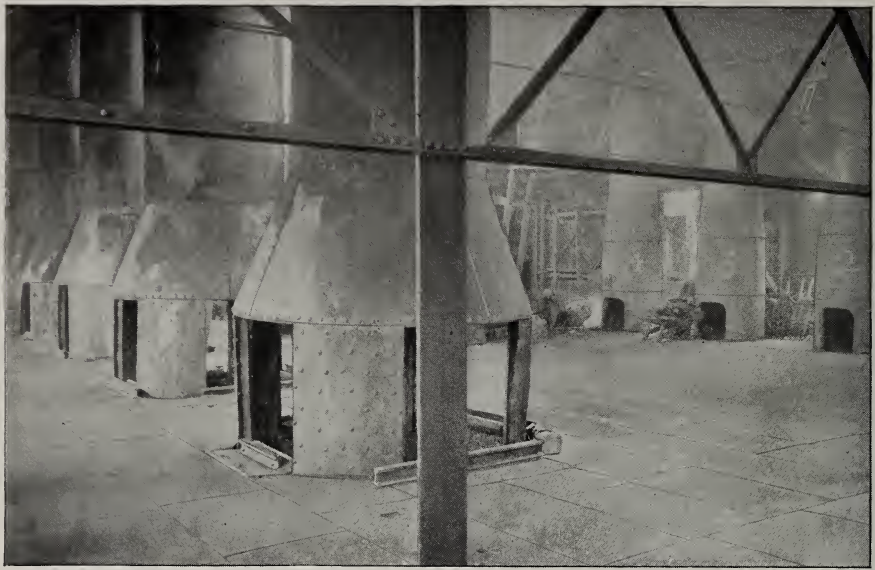
The result of using hot blast for furnaces has been to greatly increase the manufacture of pig iron, at the same time reducing the quantity of fuel used per ton as compared with the cold blast process. Although the introduction of hot blast dates back to 1829, and many systems have since been used to obtain the maximum efficiency of heating air for this purpose, it was not until the improvement of E. A. Cowper, in 1860, that the high temperature for blasts, such as are now used, 1000 to 1500 degrees Fahr., could be practically obtained. Cowper's improvement consisted in using the principle of the Siemens regenerator furnace. The stoves consist of a vertical cylindrical boiler shell, lined with fire brick, and the interior is built up of a checkered work of rectangular refractory blocks, so laid as to give sufficient space for the free passage of air between them. These blocks are now replaced by a special refractory block of honey-comb pattern.

There are at least three stoves to each furnace, so that when one is heating the blast the other two are being heated up.

THIRTY-FIVE-INCH MILL ROLLS AND TABLES AT THE CARNEGIE WORKS



A SLABBING MILL OF THE ILLINOIS STEEL COMPANY



CHARGING FLOOR OF IRON AND SPIEGEL CUPOLAS. THE ILLINOIS STEEL COMPANY

After one of the stoves has been heated for about two hours by means of the waste gases of the furnace, which are burned in the lower part of the stoves, their products of combustion passing through the stoves, the gas is turned off and a cold air blast is introduced, which, in passing through the hot checker work, takes up the heat from the same surfaces that previously had absorbed it, and in this condition the air is forced through the tuyeres into the furnace.

We have, in the preceding, had a general oversight of the manufacture of pig iron from the ore to the iron in the moulds or the mixer. The mixer, as shown on the opposite page, consists of a large iron vessel, lined with fire brick, and has a capacity of several hundred tons. It is mounted on trunnions and can be tipped by mechanical means. On top is a hopper into which the metal is run from a ladle on the overhead track leading directly from the furnace. Below, and in front of the mixer, is another track with a platform and weighing scale. The empty ladle is run on this scale, weighed, and filled with molten metal from the tapping door as the mixer is turned down. By the use of the metal mixer, a constantly uniform grade of pig iron is furnished either to the Bessemer or the open-hearth department, where it is subsequently turned into steel.

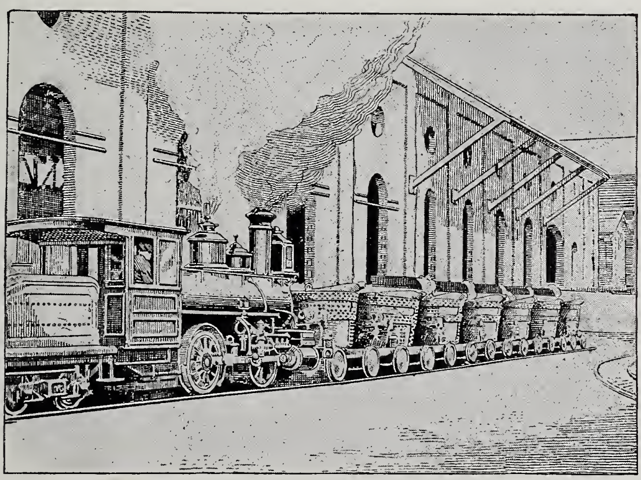
Steel, which now almost universally takes the place of its old companion, wrought iron, has no specific definition, but may be understood to be the compound produced by what is known as the cementation process, or the malleable compounds of iron made in the crucible, Bessemer converter, or the Siemens-Martin open-hearth furnace.

The steel produced by the crucible method is generally known as blister, or cement steel. It is produced from a high grade of pig iron. Much of this is procured from Sweden, and owing to this fact it is very expensive, and its use is restricted to the manufacture of cutting tools, files, etc.

From the mixers above mentioned the molten metal is carried over an elevated standard gauge track to the converting works, where it is at once poured into one of the large Bessemer converters, holding about 10 tons, from which it eventually issues as steel. The Bessemer process, briefly described, consists in blowing air into the liquid

pig iron contained in the converter for the purpose of purifying the iron, that is, burning out, or oxidising, the silicon, manganese, and carbon of the pig iron, forming slag and carbonaceous gases, which are readily removed from the mixture, the former by skimming and the latter passing off with the blast in the form of carbonic oxide and carbonic acid gas. The pig iron in the converter is kept liquid by the heat produced from the burning of its silicon and carbon contents.

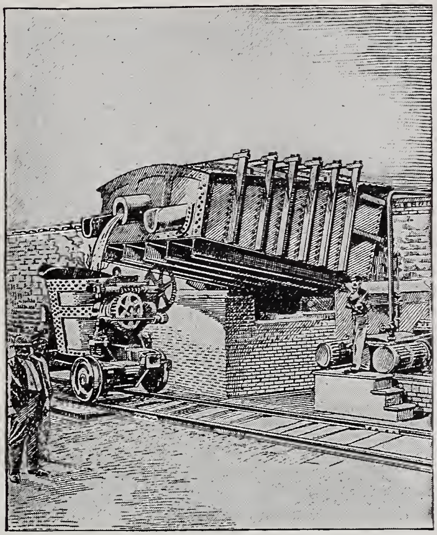
Experienced operators note by the colour of the flame coming from the mouth of the converter when the combustion of the carbon is complete, the time occupied being generally from eight to twelve minutes. Suitable quantities of ferro-manganese or spiegel iron, containing known quantities of carbon, are then added to the steel in the converter to give it the proper percentage of carbon, and to reduce to metallic iron such oxides of iron as may have been formed during the operation. By hydraulic devices under his control, the operator turns the converter, stops the blast, and pours the purified metal into a large ladle, which, in turn, carries it



A TRAIN OF LADLE CARS

over a series of moulds, made of cast iron, and of suitable size, into which the molten steel is poured.

While filling these moulds several test casts are taken from the ladle, representing the average quality of the steel for that particular "blow" of the converter. A number is given to this so-



A METAL MIXER

called blow, which follows the steel throughout its entire subsequent workings, and careful records are kept of the chemical and physical properties of the metal, whether called for by the specifications or not, so that at any time reference can be made to them if desired.

If the lining of the converter be made of a highly silicious material,—that is, the ordinary refractory kind,—it is called an acid converter; if it be composed of limestone or dolomite, it is called a basic converter. The question of the lining of the converter depends entirely upon the chemical composition of the pig iron to be treated, the resultant steel being of practically the same quality in both cases. The con-

ROLLING OPEN-HEARTH STEEL FURNACES AT THE ILLINOIS STEEL COMPANY'S WORKS AT SOUTH CHICAGO

verter department must be supplied with the necessary hydraulic cranes, ladle and bottom houses for repairing the ladles and bottoms of the converters, which must be constantly repaired, and also with the necessary cupolas for melting the pig iron, in the event that liquid metal is not taken direct from the mixers. The department must have its own blowing engine installation, and ample railway facilities for the prompt delivery of empty ingot moulds, and shipment of those that are filled to the stripper.

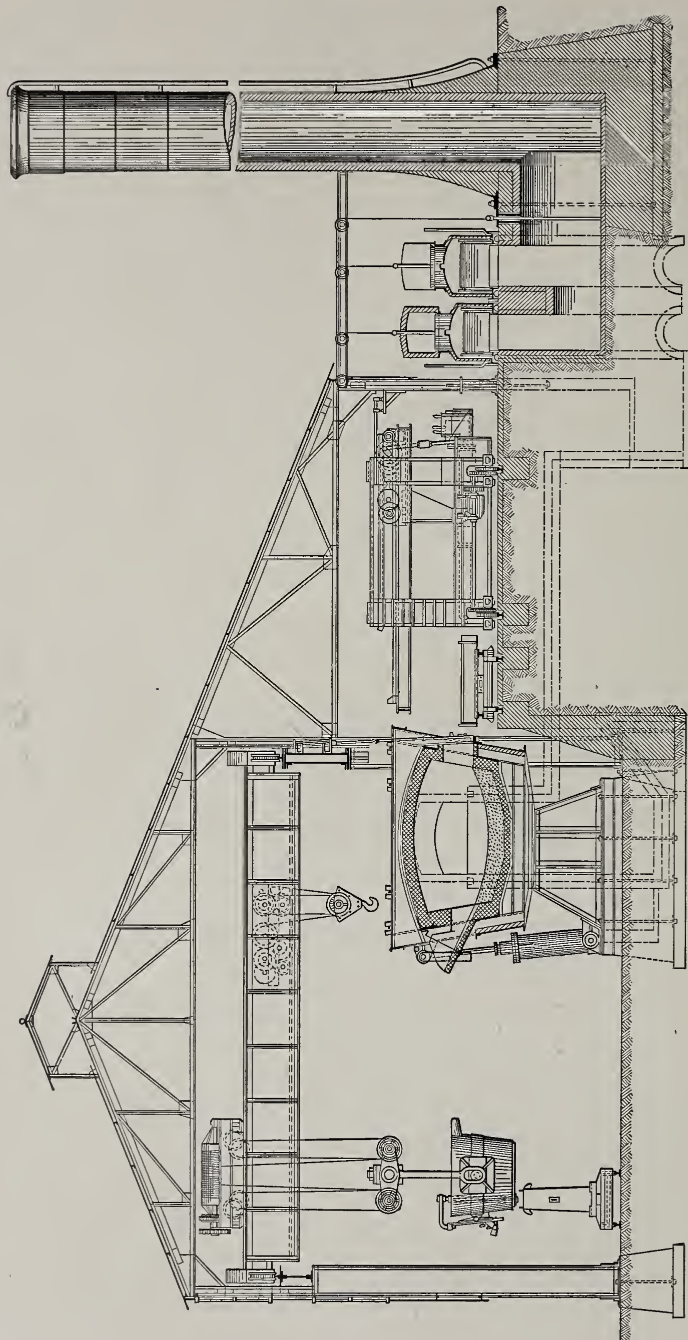
Ten years after the invention of the Bessemer process Messrs. E. and P. Martin, of France, succeeded, by the use of the Siemens regenerative furnace, in the manufacture of what is known today as open-hearth steel.

The open-hearth process consists in melting pig iron with more or less wrought iron or steel scrap in a furnace by means of the direct action of a flame, and converting the resultant liquid metal into steel. The flame is generally produced by means of a regenerative gas furnace, as it is quite impracticable to produce in any other way the heat required. The temperature of the interior of the furnace and of the molten metal is estimated by the eye, deep blue glasses being used as a protection against the intense glare. It is essential that the melter be highly skilled in his profession, as, if the metal is too cold, it is hard to cast, and if too hot, bad heats will follow.

The same chemical process in burning out the impurities takes place in the open-hearth furnace as in the Bessemer converter, except that the combustion of the carbon is not made complete, but is stopped when the proper amount is found to be contained in the mixture, necessitating a slower operation, thus giving ample time to make tests, and insuring a uniform product. The molten steel, when found satisfactory in composition, is run from the furnace through a tap-hole into a large ladle, which, in turn, pours its contents into ingot moulds, substantially as in the Bessemer process just explained, test casts being taken for chemical analysis, and the heat number carefully recorded.

SOAKING PITS AT THE CARNEGIE STEEL COMPANY'S WORKS

The furnaces are generally of from 40 to 50 tons capacity, and two heats per day are usually made. Two forms of furnace construction are in use,—one in which the frame of the furnace proper is stationary, and another in which this frame can be tipped. The latter construction is shown on pages 268 and 270, the second representing a section through an open-hearth department



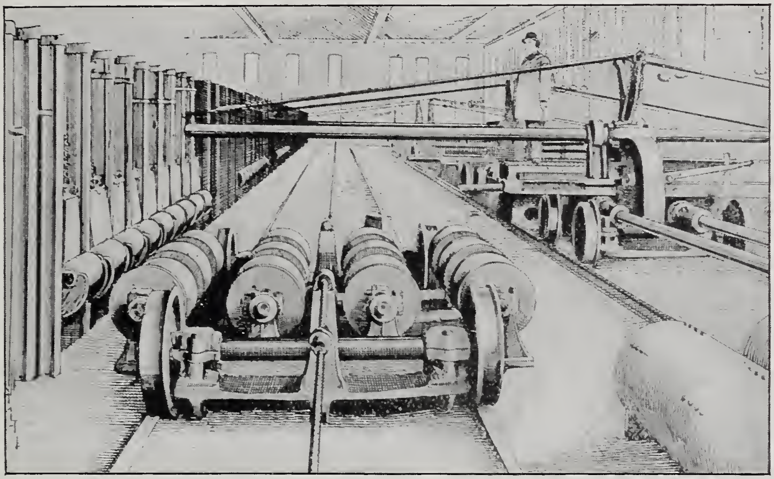
A SECTION THROUGH AN OPEN-HEARTH STEEL DEPARTMENT

equipped with what is known as the Wellman electrically controlled charging machine, which in the United States is now universally employed for both styles of construction.

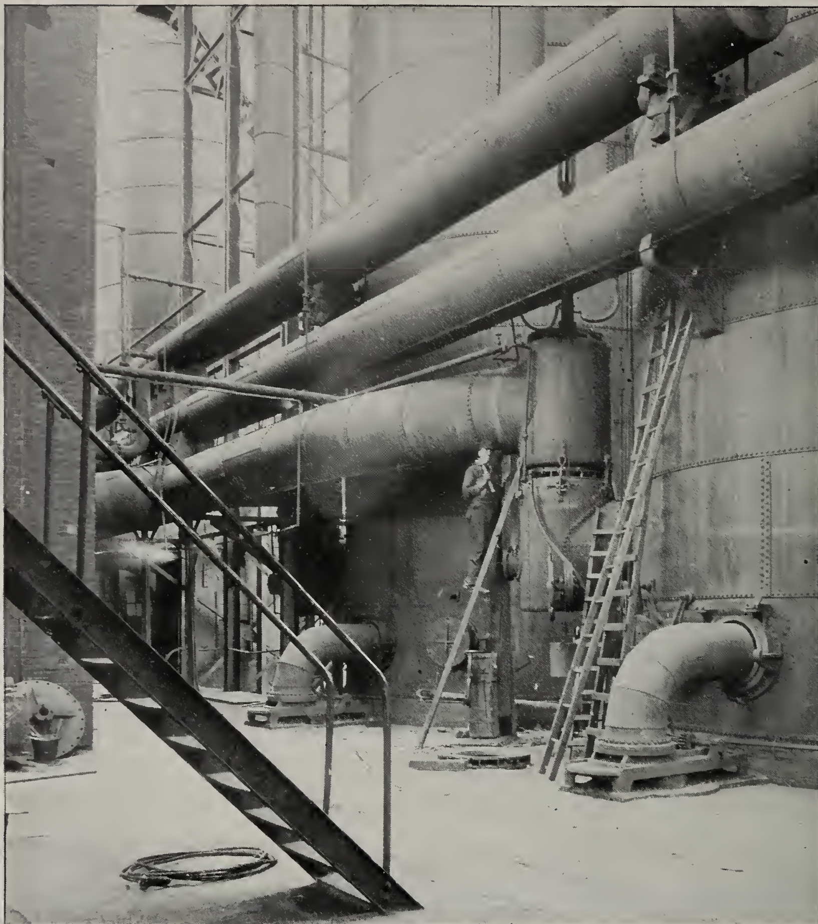
The moulds into which the steel was poured rest on a train of small cars which are drawn by a donkey engine to a machine called the "stripper." This is a hydraulic ram used for forcing the partly cooled steel (which has taken the interior form of the mould) from its surroundings, the empty mould being again placed on cars and carried back to the converter house or open-hearth department to be filled anew.

The steel ingots, which still retain a large percentage of their initial heat, are not allowed to cool entirely, but are immediately transferred, by means of cars, to the various rolling mill departments to be reheated prior to being rolled to the desired shapes. The partly cooled ingots are quickly placed into re-heating furnaces, or so-called soaking pits, and are allowed to remain until uniformly heated throughout, and also to give the temperature necessary to obtain the best results in rolling. Having attained this temperature, they are taken out of the furnaces by means of electrically controlled tongs and are carried to the feed table of the rolling mill.

Here we shall have to make a slight stop in the process of the manufacture and say a few words on rolling mills. Rolling mills, devised for the purpose of compressing, elongating, and finally forming the ingot into the desired shape, are generally distinguished by the name of that product which they are designed to roll. They differ materially in mechanical structure, in requisite horse-power, usually from 1000 to 4000, but running up as high as 10,000, and in general design. There are, for example, rail and billet mills, blooming mills, bar mills, cogging mills, shape or beam mills, slabbing mills, plate and universal plate mills, blooming, cogging and slabbing mills being the preparatory mills to rolling the finished rail, shape or plate, respectively. In these mills the steel obtains its first working, to be subsequently transferred automatically to the rail, billet or bar mill for manufacturing rails, billets or bars, the shape mill for manufacturing beams or other shapes, and the plate mill or universal plate mill for the manufacture of plates. It is evident from the foregoing that the same mill cannot be used for the manufacture of the various classes of finished products, nor can we even use with economy the same mill for different sizes of the same product. The Carnegie



CHARGING BLOOM FURNACES



HOT BLAST STOVES AT THE WORKS OF THE ILLINOIS STEEL COMPANY

Steel Company, for example, have, for rolling beams, three separate shape mills; for rails, two separate rail mills; and for plates, six different plate mills. Immense plants are, therefore, necessary to roll all sections that may be called for.

As the tonnage of rails is, without question, the largest of all finished steel products, it may be interesting to describe their manufacture from the steel ingot, as practised at the Edgar Thomson Steel Works of the Carnegie Steel Company. After the ingot has attained the proper temperature for rolling in the soaking pit, it is placed upon a feed table leading to the blooming mill. This mill consists of a three-high train of rolls, operated by an engine with a 50-inch cylinder and 72-inch stroke. The tables are operated by an independent double 9″ × 12″ engine. In this mill the ingot receives its first working, and is reduced in the rolls from a size seven feet long, about 16″ × 18″ at the top and 19″ × 21″ at the bottom, to an approximate 8″ × 8″ square bloom in seven passes. This bloom runs on tables and driven rollers to the shear, where it is cut into shorter lengths.

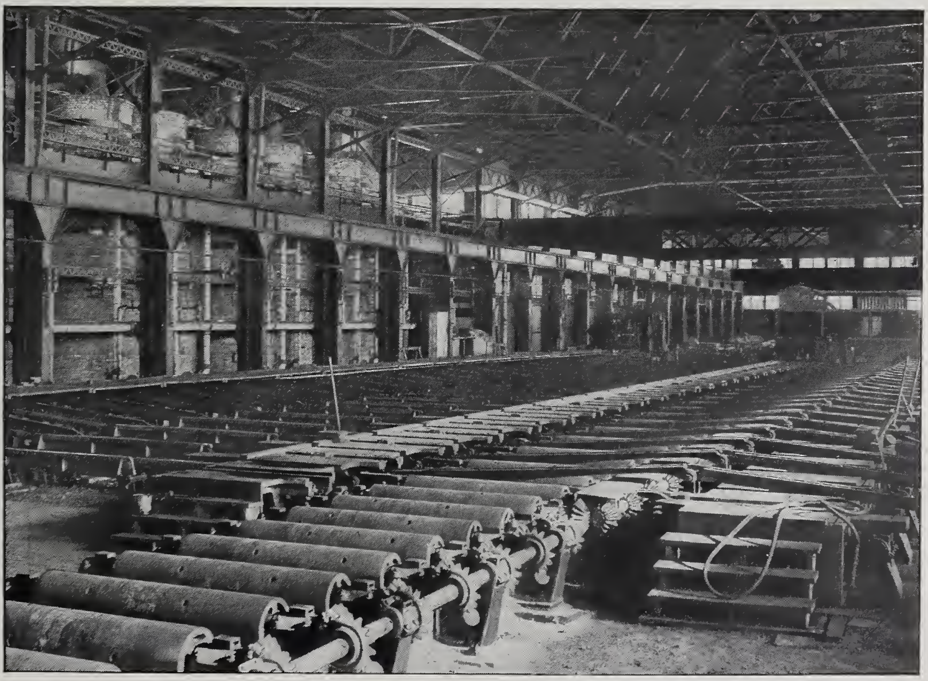
After cutting to length, the blooms are delivered on a series of driving rolls to a car on a track back of a long line of reheating furnaces, into which they

are placed, to be reheated. By an underground trolley the car may be moved in front of any door of the furnaces. Each line of furnaces has a charger which pushes the bloom from the car into the furnace (see page 271). In front of the furnaces is a similar apparatus for drawing out the hot blooms upon the car, which runs to driven rollers, carrying the bloom to the table of the first roughing train, which consists of a three-high set of rolls, and in which the first five passes are made. The next five passes are made in a second three-high 24-inch diameter mill, called the second roughing train, to which the first delivers directly. The last, or finishing pass, is made in a two-high train of 24-inch rolls, called the finishing train. Each train of rolls is driven by its own engine, the first having a horse-power of about 1500, the second of about 3000, and the third of about 1000.

The entire mechanism is as nearly automatic as it can be made, one man handling the hydraulic valve levers which operate the tables, move the various apparatus, etc. Each train has a hydraulic crane for changing the rolls, which, for rails, is done very quickly. From the finishing train the rail is carried on driven rollers through a set of marking rolls, which stamp the name of the manufacturer and the date on the webs of the rails at fixed intervals, so that at any time they can be traced back to the chemical and physical qualities of the steel from which they were produced. Leaving the marking rolls, the rail is carried to the hot saws, where a four-length rail can be cut to 30-foot lengths.

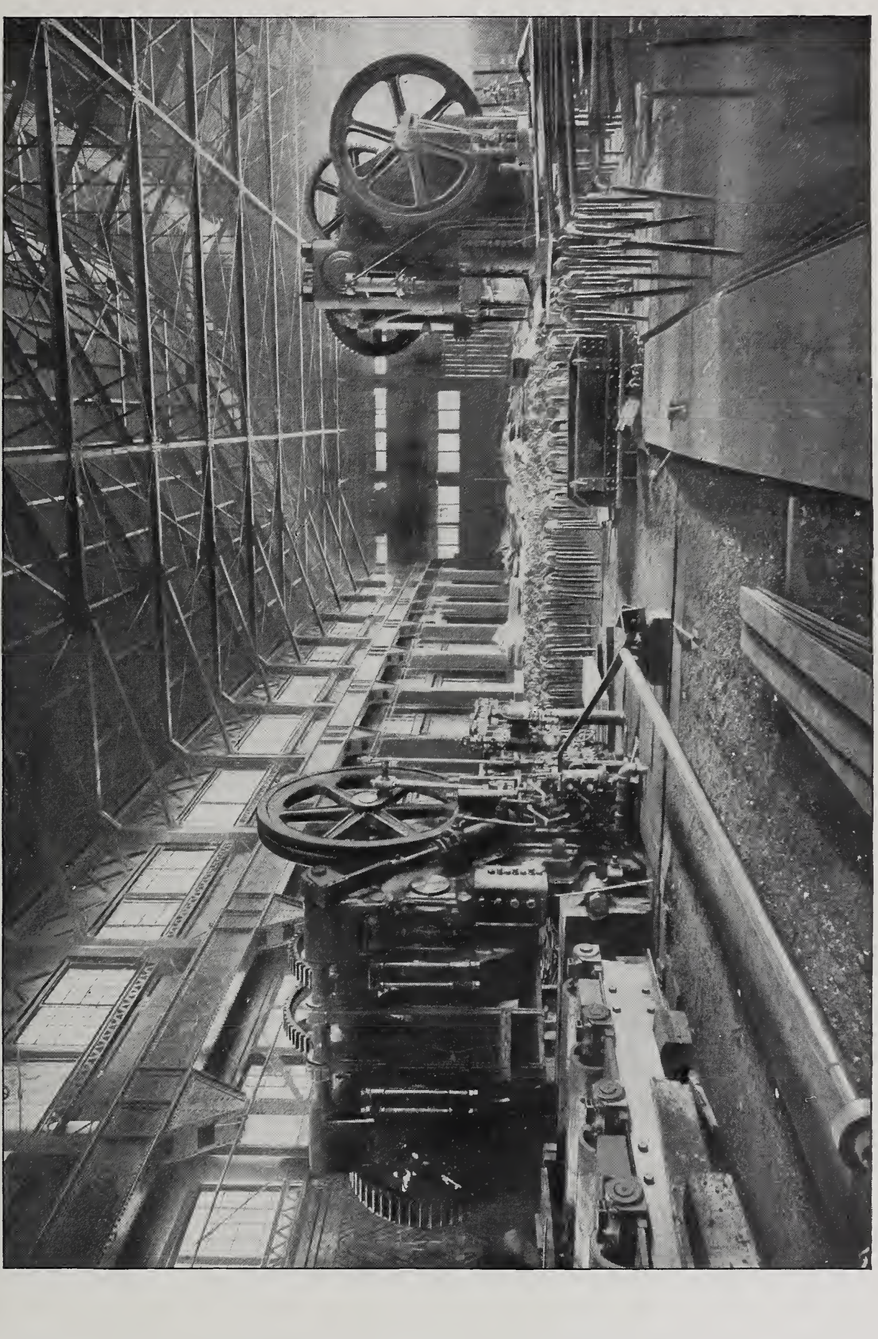
After having been cut to length, the rails travel on another set of driven rollers, and are placed on the hot beds by pushers driven by means of winding cables. The hot beds are about four feet above the floor, and are composed of a set of skids made of rails. The end of the hot beds connects with the finishing departments.

After the rails have passed over the hot beds they reach the straightening

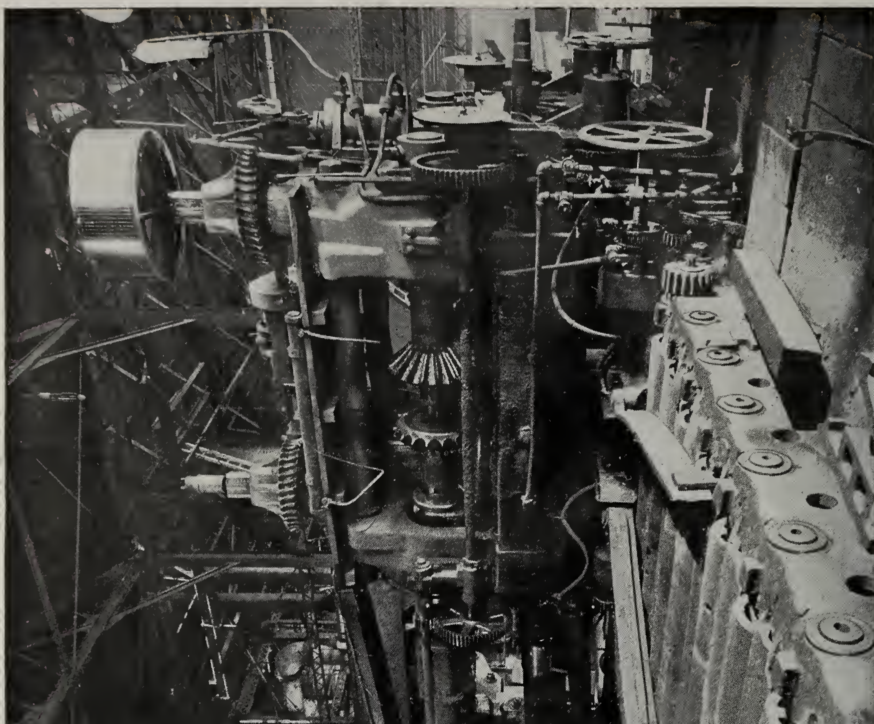


STRAIGHTENING AND COOLING TABLES

A MERCHANT MILL AT THE MILWAUKEE WORKS OF THE ILLINOIS STEEL COMPANY



LARGE SHEARING MACHINES IN THE PLATE MILL AT THE CARNEGIE WORKS



FORTY-EIGHT-INCH MILL ROLLS AND ENGINE AT THE CARNEGIE STEEL COMPANY'S WORKS

department, which is another building parallel to the rolling mill proper. From the hot beds the rails are carried on a line of driven rollers which extends the whole length of the finishing department. The rollers are driven by two small reversing engines, so that the rails can be sent forward or backward, as desired. When the rail reaches the proper point, two arms are raised by the action of a steam cylinder and piston, controlled by a lever. These arms lift the rail from the rollers, and the rail slides down on to the cold bed close to the straightening presses, where, after being straightened, they are drilled by multiple drills. The finished rails finally are pushed out of the side of the building, to the loading beds which are arranged just above the level of the flat gondola cars, so that loading for shipment can be quickly accomplished.

Similar methods of rolling apply to sections other than rails. Owing to limited tonnages of fixed sizes, however, no such special and highly automatic working plants as used for the manufacture of rails are in use. For I and channel beams the ingot is first reduced to the form of a clumsy-looking I-beam in the cogging mill, which is independently driven. From there the rough shape is carried on a line of driven rollers to the shape mill, where it is subsequently reduced to the finished I or channel, as the case may be. The shape mill consists of a first, second and third roughing train, and a final finishing train, each composed of a set of three-high rolls. These are driven by the same engine, placed at one end of the series of rolls, the rolls themselves acting as shafts to drive those not connected direct, suitable couplings being applied between the ends of the rolls, making them continuous. For different sizes and weights of shapes, different diameter rolls, as well as mills, as already explained, are used on the score of economy.

A RAIL MILL OF THE ILLINOIS STEEL COMPANY

The exact shape, after leaving the last finishing pass of the rolls, has, first, a

test piece cut from its section, is then stamped with its "blow" number, representing the constituents of the steel, and is cut to ordered lengths by means of a hot saw. After this it is delivered to the hot beds, and is finally straightened in the straightening department, already explained for rails. From there it is sent to the shipping yard, or to the finishing department if subsequent work is to be performed on it. The test piece which was cut from the beam is sent to the testing laboratory, where its elastic limit, ultimate strength, elongation and fracture are carefully measured and recorded, with the chemical constituents of the steel from which it was produced.

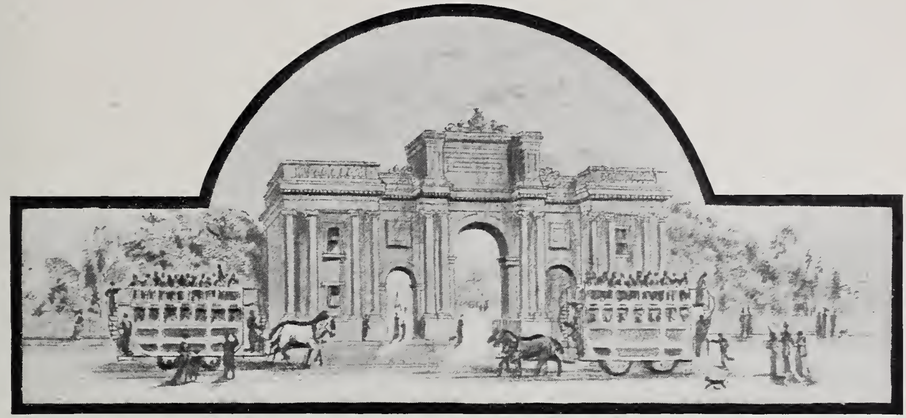
For plates, the ingot is first reduced to a slab, in the preparatory mill, called slabbing mill, which slab, as a rule, is reheated in a reheating furnace, extracted from this by a machine and then rolled flat to the required width and thickness in a plate mill. Plates having a width of over 48 inches, or less than ¼-inch thick, are rolled in an ordinary plate mill,—that is, one having only horizontal rolls,—and plates rolled in such a mill must have their edges sheared in the direction of the length of the plate, subsequent to rolling and straightening. For plates under 48 inches in width and over ¼-inch thick, this shearing is not necessary, as true edges can be obtained in a plate mill having, besides the same horizontal rolls as the ordinary plate mill, a set of vertical rolls. Such a plate mill is called a universal plate mill.

Plates six inches and less in width are known as bars, and are worked in grooves cut into rolls similar to those for shapes. This being a less expensive process than that used for plates, most bars are rolled in this manner.

All plates, after being rolled to the required width and thickness, are apt to be buckled, owing to internal stresses or unequal heating at different points, and must, therefore, be straightened. This is accomplished by means of subsequent rolling for wide plates, and by means of straightening tables for long and narrow plates, as turned out by universal mill plates. After straightening, plates are carried on a long roll table to the templet department, and laid off to templet, all this being performed while they are on the roll table. From there they are transferred to the shears, placed at the extreme end of the plate mill department, and cut to the templet marks thereon. They are then directly shipped on cars to their destination.

What has been given in the foregoing pages represents simply what might be termed a bird's-eye view of the several processes entering into the manufacture of structural steel, from the ore to the finished product; but with all its necessarily superficial character, the article, it is hoped, will serve a useful purpose.

The writer wishes to express his thanks to the Carnegie Steel Company, Ltd., for extending to him the use of some of the photographs and data which have been incorporated in the preceding pages.



ENTRANCE TO HAMILTON PARK, BIRKENHEAD, SHOWING GEORGE FRANCIS TRAIN'S ORIGINAL TRAMWAY CARS, 1860

BRITISH TRAMWAY DEVELOPMENT

By J. Clifton Robinson

IT is a matter of history that the initial attempt to introduce tramways in Great Britain was made at Birkenhead in 1860 by George Francis Train. Later developments have brought much more brilliant successes, but the meed of praise due to the pioneer methods is none the less. As years have passed, new demands have arisen in the construction of the permanent way and in devising the method of traction best applicable to each projected scheme. Inseparable from, yet incidental to, the initial stages of tramway enterprise, have been the proposals to secure local assents and support, with the necessary parliamentary powers. All the preliminary negotiation, and arrangements for the carrying out of the work, such as the proper selection of routes, character and demands of each city, town or district through which the lines were projected, have had to be encountered, and the question of motive power, whether horse, steam, cable, or electricity, the design of power station, rolling stock, and equipments generally have had to be considered and dealt with from the standpoint of local conditions and environment.

When the tramway manager-engineer of to-day receives instructions from his board to lay out a new system of tramways or to reconstruct an old one, he finds, ready to his hand, an immensity of ascertained facts and a complete armoury of precedents in practice regarding installation, methods of road-bed, construction, equipment, and modes of traction. Forty years ago the problem was at once simpler and also more novel. When it was first proposed to lay down a tramway, the general idea was merely to fill the place of cab or omnibus, and the horse presented itself as the prevailing idea for haulage. Thus it came to be that tramway engineering concerned itself only with the most primitive form of rail that would give comparative smoothness to the track and lighten the burden on the horse.

Without going into the question which has sometimes been raised whether the name tram road was derived from the name of an engineer or

THE OPENING OF THE BIRKENHEAD TRAMWAY, AUGUST 30, 1860

from the resemblance of the first wooden rails used to the tram of a cart, it may be noted that the idea of a railed roadway for horse haulage was not quite new in Great Britain in 1860. In discoursing on this subject about eighteen years ago the writer pointed to the interesting historical incident that, at the battle of Prestonpans, in 1746, a colliery roadway, from Tranent pit to the little harbour of Cockenzie, and which served as a position for Cope's Artillery at that famous fight, was nothing more or less than an early form of tramway; and on steep roads in several towns it was always possible to find examples of stone

FIG. 1.—SECTION OF TRAIN'S TRAMWAY AT BIRKENHEAD

or iron wheel tracks laid down to dimin ish friction.

As early as 1837 there was an attempt, successful for a time, to introduce a tramway in the city of New York on these simple lines. Necessity was there the mother of invention. Roads in America were primitive, mud in winter, and deep in ruts and dust in summer, and a defined wheel track was regarded as an improvement. It was twenty years more before tramways in anything like the modern form were seen in America, New York again claiming precedence, followed, in 1856, by Boston and Philadelphia. It is notable that the engineer of the New York line was a Frenchman, M. Loûbat, and that the same gentleman laid down in Paris in 1854 a system of rails from the Place de la Concorde to Passy.

Matters were in this condition in 1857 when Mr. George Francis Train entered upon the task of introducing tramways into Great Britain. Parliamentary powers were sought, but he was opposed by Sir Benjamin Hall, then Chief Commissioner of Works; a very sturdy opponent of tramways also arose in Mr. Beresford Hope, and this joint opposition was mainly instrumental in causing a ten-years' delay in the development of tramways in the United Kingdom.

The " step rail," which held its place in America for many years, was adopted by Mr. Train. It was of rolled iron, weighing about 50 pounds per lineal yard. The rails were spiked to 8″ × 6″ timber longitudinals, these again being spiked through iron knees to cross-ties.

Failing to obtain statutory powers, Mr. Train patented his system in April,

FIG. 2.—A "STEP-RAIL."

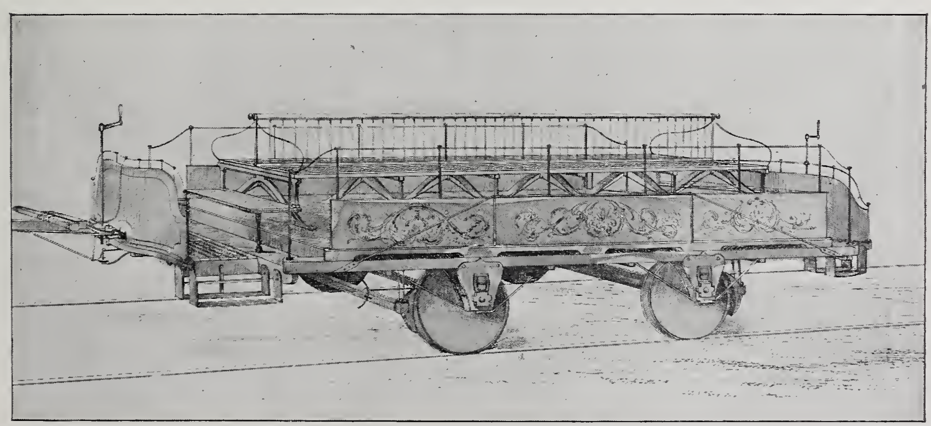
1860, and in the following year he proceeded to lay down several lines under provisional agreement with local authorities. From the Marble Arch along Bayswater Road, from Westminster to Victoria Station and on the Surrey side from Westminster Bridge to Kennington Park, Mr. Train's lines were opened; but there arose such a violent agitation against the system that the step rails were, after a brief existence, compulsorily removed, and thus tramways disappeared for a short time from London.

The agitation was based on two considerations:—The tread of the rail was about an inch lower than the carriage way adjoining the track. The railway gauge of 4 feet 8½ inches had been, it is historically known, adopted in Great Britain from the accidental fact that carriages were at that time generally built to that gauge. Hence, the tramway being precisely of the same gauge, it became almost impossible for a private carriage to leave the step of the rail within the tracks without a violent wrench and sometimes only with the loss of a wheel. The alternative was to

GEORGE FRANCIS TRAIN, 1860

deny to private vehicles the use of the centre of the road. The second consideration was that the tramway was merely ballasted, not paved (as is now uniformly the case), and the macadam speedily rutted both inside and outside of the iron rail.

Mr. Train had been more successful



AN OPEN TWO-HORSE CAR DESIGNED FOR THE EARLY BIRKENHEAD TRAMWAYS

THE MARBLE ARCH, OXFORD STREET, LONDON, SHOWING TRAIN'S ORIGINAL TRAMWAY CARS, 1861
THE RAILS WERE REMOVED MANY YEARS AGO AND WERE NEVER RELAID

at Birkenhead. In six weeks after sanction was obtained to lay this pioneer example of a street tramway the construction was completed, and the line was opened, amidst great public demonstrations of approval, on August 30, 1860. A large banquet was held, on the invitation of Mr. Train, who boldly invited all the crowned heads of Europe, "excepting the King of Naples" (who was unpopular at the time), and every prominent person in politics, commerce, letters and public life generally. About 300 gentlemen attended the banquet, and thus was inaugurated the oldest existing tramway system in Europe, for although it is true that T. M. Wiswell's grooved rail superseded the "step rail," and that the Birkenhead tramways are at length conforming to modern improvements, the two miles of main route, as originally operated by Mr. Train, still, after many vicissitudes, form part of the existing system.

In the year 1863 Mr. Train laid down a tramway of nearly four miles between Burslem and Hanley, and this route still subsists as part of the North Staffordshire tramway system. Mr. Train also obtained a concession for a horse tramway in Darlington, now, after varying fortunes, financial and otherwise, about to be electrically converted and extended, in common with that of Dublin, Bristol, Middlesborough, Glasgow, Liverpool, and nearly every other city and town. But as regards London,

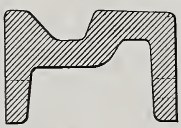


FIG. 4

Mr. Train's labours have "left not a wrack behind," although recent developments encourage the belief that the enlightened views of statesmen may yet prevail. Sir John Kennaway, as chairman on the London United Tramways Bill of 1898, voicing the sentiments of his committee, urged that the congested state of London made the speedy adoption of electric traction on tramways necessary, and that its benefits should be secured to the people of London at the earliest possible date. Such advocacy should go far to neutralise those Silurian

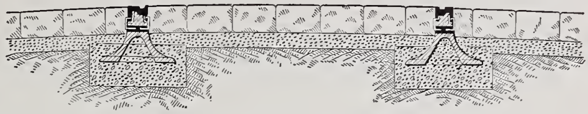


FIG. 3.—BRISTOL TRAMWAYS

ideas which have hitherto delayed progress and deprived the metropolis of the British Empire of its natural right of expansion and of intercommunication with greater London.

In 1862 Mr. John Haworth endeavoured to improve on the "step rail" on a line constructed at Pendleton, Salford. This consisted of about two miles of flat rails, bolted to longitudinals laid to suit the omnibus gauge, and in the centre was a grooved rail into which a small guide wheel, carried under the fore part of the omnibus, and controlled by the driver, was dropped or removed at will. This line developed some serious faults, and, after a short existence, was removed.

Tramway enterprise remained dormant in Great Britain until 1868, when a company obtained powers to construct a system of tramways at Liverpool, in which year the first British act authorising the construction of a passenger street tramway was passed. The line was opened in 1869, and was quickly followed by the agitation for a general statute to regulate the procedure between tramway companies and corporations. The Tramways Act of 1870 was passed, and while in its general character as well as in its result this act has done much to repress and retard tramway development, its first effect was to stimulate the desires of the principal towns to obtain the advantages of this new method of transit.

In the twenty years ended in 1887 about four hundred bills and provisional orders were promoted. In the subsequent twelve years Parliament and the Board of Trade were kept busy in au-

thorising the conversion of lines to mechanical traction, and in general legislation in connection with electric power, and more recently by the Light Railway Act, 1896, the provisions of which have given impetus to tramway development on suburban and inter-urban lines.

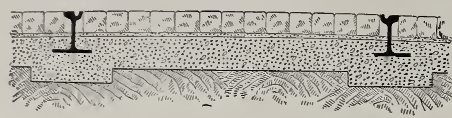


FIG. 5.—EDINBURGH TRAMWAYS

In 1875 the writer entered on the organisation and general management of the Bristol tramways. The light iron rails elsewhere used, spiked on to wooden longitudinals, had made a fairly good-looking job, but the system had two serious defects. The vertical spikes soon developed a tendency to work up, thus slackening the joints, destroying permanency and the desired smoothness. Costly repairs soon became neces-

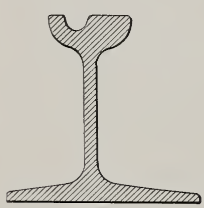


FIG. 6

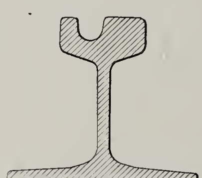


FIG. 8

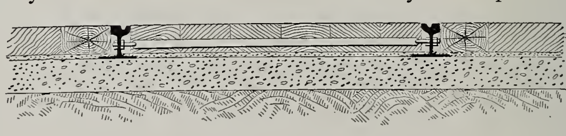
sary, and evenutally an entire renewal of the permanent way. In the first stage of improvement an iron substructure was adopted in lieu of the timber longitudinals, but the use of the independent rail and chair was retained.

At Bristol, the rail as originally laid was of the design shown in Figs. 3 and 4. The chairs, placed at distances of 3-feet, were of cast iron, with a base of 14 × 12 inches, and the rails were fixed to the chairs by dogs of half-round iron. Here the upspringing of the vertical spikes was removed, and, given a sound foundation for the chairs, the roadway was not deficient in good qualities. The suspension of the rails between the chairs was not, however, wholly satisfactory, and in later systems this has been wholly avoided by the universal adoption of the steel girder rail.

On proceeding to Edinburgh, in 1882, to take up the general management of the extensive system of horse tramways which in ten years had been developed there, the writer found that the substitution of the girder rail, patented in 1878 by Sir James Gowans, had become general. The Gowans rail, as first made, weighed from 73 to 102 pounds per lineal yard, the dimensions being, depth, 7 inches, and breadth of sole, 7 inches. The rails were laid in a bed of concrete, and the paving consisted of granite setts. Chilled steel blocks with diced surface were laid alternately with the granite blocks at each side of the rail and the whole was thoroughly grouted and bonded together with bituminous tar.

We have thus seen brought into practice a form of road-bed gradually advancing in costliness, and at the same time advancing in efficiency and durability. In twenty years the entire method of construction had been revolutionised, and at each stage the capital involved had been increased. The only conclusion possible was that some method of increasing the revenue from passengers and decreasing the working cost must be found. And this leads us to the point of mechanical traction.

The forty years of tramway experience appear to divide themselves into four distinct periods, the ten years from 1860 to 1870 being the seed time, the decade to 1880 the period of development of horse tramways, the period to 1890 being that in which the necessity for improved



FIG, 7.—LONDON UNITED TRAMWAYS

methods of haulage became clamant, while the last ten years have seen the rise of newer and better things.

The constructional failure of the earlier methods was the first point of departure. There was no difficulty in

HIGH STREET, STOCKTON

perceiving that, with horse haulage, itself absorbing over 40 per cent. of the gross revenue, few lines could bear the capital outlay necessary for reconstruction. And over and above its costliness, its liability to great fluctuations, in cost of feeding and renewal, and its undesirable unsanitary accompaniments, horse haulage was entirely non-elastic. While it might be easy to reserve cars to meet exceptional traffic, it was quite impossible to face the contingency of surplus horses "eating their heads off" in anticipation of such times of pressure. The only possible relief was to seek for the best method of mechanical traction.

There were many who, in these circumstances, turned to steam as the first idea. The rail and flanged wheel had been borrowed from the railway. Why not also the locomotive? But the use of a steam engine in the streets of a town was altogether objectionable, and the fact that in nearly every case where tried they have been abolished goes far to justify that objection. Locomotives as at first offered for acceptance were totally unsuitable for street traffic, and although the noise and smoke were eventually got rid of, or at least minimised, steam engines in their most presentable form still remained ungainly and unpopular. In Bristol, in 1880, locomotives were tentatively adopted, the power being supplied under contract at 7d. per car mile. But the engines found no favour with the company, and the loss in working proved so discouraging that on all sides it was found undesirable to continue the contract.

Apart from locomotive steam power, the only available substitute for horse haulage twenty years ago was the cable. Speaking before the Royal Scottish Society of Arts in 1883, after quoting expert opinion, that, as regards electric power, "there is at present nothing in the market worthy of attention," the writer added:—"I trust we have an open mind for future improvements." But between 1883 and 1888 these improvements had not arisen, although some advances had been made, and in those five years some of the largest in-

THE CITY TERMINUS, BRISTOL, OLD MARKET STREET

stallations of cable traction were made in the United States.

The disadvantages of horse haulage are so many that almost any change is beneficial, both to the public and to the operating company. Not only was horse haulage so costly that it necessitated relatively high fares, but the health and condition of the stud formed a constant burden of anxiety, and the cost of fodder was liable to frequent and violent fluctuations. Add to this that the public, while incessantly calling for increased service, was as constantly complaining of the slow speed attained by the cars.

The steam locomotive did not meet all these points, while it introduced new troubles of its own. After all, a team of horses was a pleasanter sight than some of those rattle-boxes of machinery found on steam tramways. If the street was cleaner, the air was fouled in a new and most obnoxious way, and the locomotive occupied as much of the roadway as a pair of horses. Then the open outside seats, ever so popular in Great Britain, were rendered untenable from the fumes and cinders. Despite some successes, there has been no proof that a favourable permanent solution of the public or financial requirements of an average tramway has been found with steam traction.

With the cable system, a solution seemed for a time to have been discovered, but with limitations, and a solution with limitations is of no permanent value. When the big rush of a holiday or a public fête came, it was as easy to run ten cars as one,—and not very much more costly. Gradients presented little or no difficulty, trains of cars could be introduced, and the carrying power of the line thus increased. But here the "limitations" arose. Unless the traffic was heavy and constant, the cost of haulage became ruinous. A large percentage of the motive power was absorbed in hauling the cable alone, and with even one car running,—or with no car running,—the fixed charges remained, and so handicapped the system.

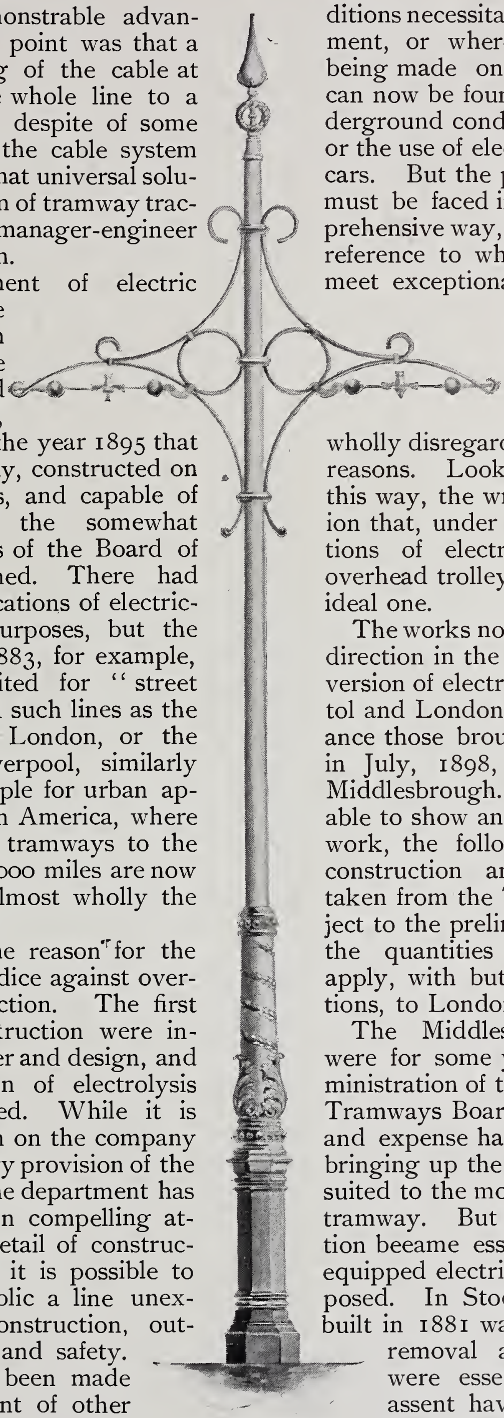
It was, therefore, only on congested routes that the cable system was commercially possible, and its extension into half-built districts or quiet residential quarters was impracticable. Only on

the steepest gradients had the cable any distinct demonstrable advantage. A further point was that a break or stranding of the cable at once brought the whole line to a standstill. Thus, despite of some valauable points, the cable system failed to provide that universal solution of the problem of tramway traction of which the manager-engineer had been in search.

The development of electric traction in the United Kingdom is the work of the past ten years, and it was not, indeed, until the close of the year 1895 that an electric tramway, constructed on modern principles, and capable of complying with the somewhat severe regulations of the Board of Trade, was opened. There had been earlier applications of electricity to traction purposes, but the Portrush line of 1883, for example, was totally unsuited for "street railway" use, and such lines as the underground, in London, or the overhead, in Liverpool, similarly supplied no example for urban application. Even in America, where overhead electric tramways to the extent of over 15,000 miles are now running, this is almost wholly the work of ten years.

There was some reason for the early British prejudice against overhead electric traction. The first methods of construction were inelegant in character and design, and the possible action of electrolysis was almost ignored. While it is certainly a burden on the company to conform to every provision of the Board of Trade, the department has done good work in compelling attention to every detail of construction, so that now it is possible to present to the public a line unexceptionable in construction, outward appearance, and safety.

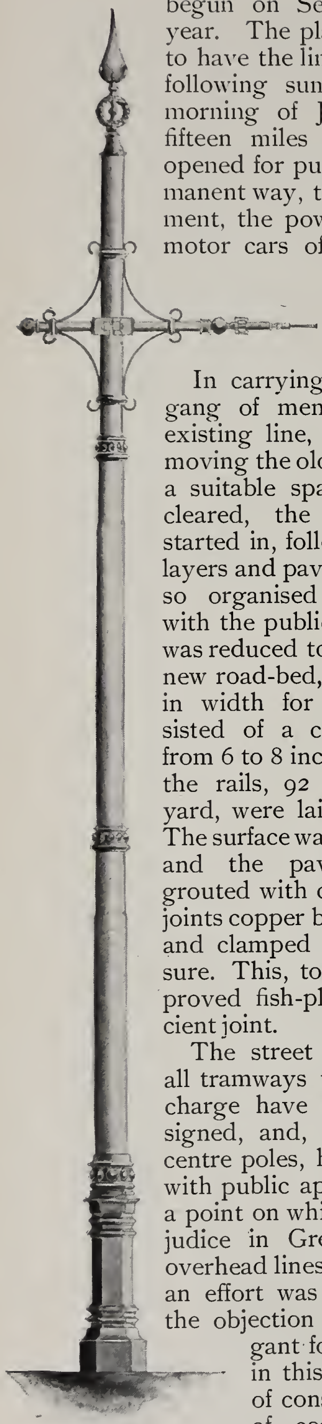
Advances have been made in the development of other applications of electricity to traction. Lines where local conditions necessitate exceptional treatment, or where experiments are being made on a practical scale, can now be found operated by underground conduit, surface contact, or the use of electric storage battery cars. But the problem of traction must be faced in a broad and comprehensive way, and not simply with reference to what may be done to meet exceptional cases, or what is possible where high financial expenditure is met by special traffic conditions, or is wholly disregarded for experimental reasons. Looking at the matter in this way, the writer is of the opinion that, under the present conditions of electric knowledge, the overhead trolley wire system is the ideal one.



A CENTRE POLE

The works now under the writer's direction in the extension and conversion of electric tramways in Bristol and London exceed in importance those brought into operation in July, 1898, at Stockton and Middlesbrough. But as it is desirable to show an actually completed work, the following figures as to construction and equipment are taken from the Tees-side line, subject to the preliminary remark that the quantities and descriptions apply, with but some slight variations, to London and Bristol.

The Middlesbrough tramways were for some years under the administration of the present Imperial Tramways Board, and much labour and expense had been bestowed in bringing up the lines to a condition suited to the modern idea of a horse tramway. But entire reconstruction beeame essential when a fully equipped electrical system was proposed. In Stockton the tramway built in 1881 was so faulty that its removal and reconstruction were essential. The royal assent having been given on August 5, 1897, the work was



A SIDE POLE

begun on September 1 of that year. The plan of campaign was to have the line completed in the following summer, and on the morning of July 16, 1898, the fifteen miles of tramway were opened for public traffic, the permanent way, the overhead equipment, the power house, and 50 motor cars of the most modern type being brought at once into successful operation.

In carrying out the work, a gang of men first assailed the existing line, excavating and removing the old materials. When a suitable space had been thus cleared, the construction staff started in, followed by the platelayers and pavers, the work being so organised that interference with the public use of the streets was reduced to a minimum. The new road-bed, extending 14 feet in width for double lines, consisted of a concrete foundation from 6 to 8 inches thick, on which the rails, 92 pounds per lineal yard, were laid to a 3′ 6″ gauge. The surface was floated in cement, and the paving blocks were grouted with cement. At the rail joints copper bonds were inserted and clamped by hydraulic pressure. This, together with an improved fish-plate, made an efficient joint.

The street standards used in all tramways under the writer's charge have been specially designed, and, whether as side or centre poles, have invariably met with public approval. As this is a point on which the original prejudice in Great Britain against overhead lines was largely rested, an effort was made to minimise the objection by the use of elegant form and good finish in this important branch of construction. The cost of construction of permanent way was practically £4000 per mile of single track, divided into two-thirds for materials used and one-third for wages.

The whole success of this work in point of efficiency and durability rested upon the two principles of using the highest class of material in construction, and of maintaining competent supervision of the work. A tramway thus laid down may reasonably be expected to last, with a minimum of cost in maintenance, for a sufficient number of years to enable a reserve fund for reconstruction to be provided from revenue.

The evolution of a perfect source of power for electric traction has proved a matter of momentous interest. From good we have advanced to better, and from better we are now advancing to perfection, although, even as perfected, the modern power house is open to improvement should some new advance be made in science or mechanical invention. The time that has elapsed since the first Bristol electric installation was brought into operation, in October, 1895, has been fruitful of invention, and in that power house as now existing, and in the central station in course of construction at Bristol, the most recent improvements will be found. Similarly, the great power house now nearing completion at Chiswick to work the extended system of the London United Tramways will display all the newer features.

As an example of a thoroughly equipped station in actual working, some particulars of the power house at Stockton-on-Tees may be given. This, placed at a central point of the system, is situated on the left bank of the River Tees, giving direct wharfage for coal and material as well as a water supply. The engines are direct-coupled to the generators, a plan now universally adopted.

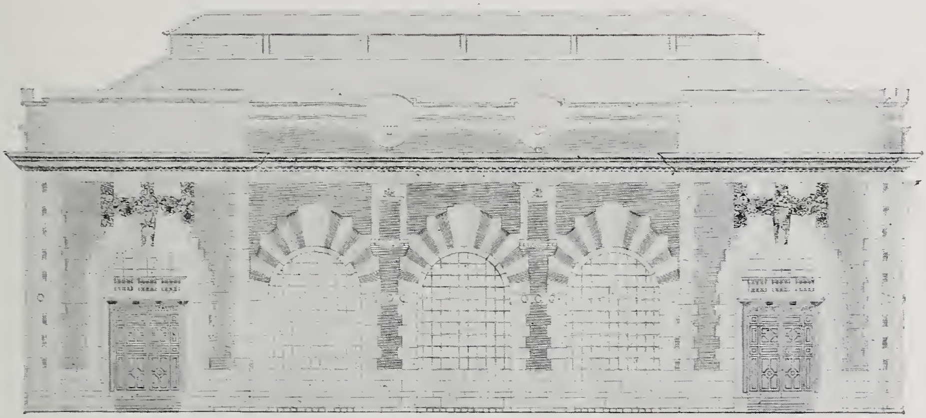
The boiler house is 78 feet by 48 feet. The boilers, three in number at present, are of the Babcock & Wilcox water-tube type, capable of evaporating 12,000 pounds of water per hour. Mechanical stokers, worked by an electromotor, are in use, and the fuel, taken from barges on the river by an electric hoist, is conveyed to the bunkers for

direct supply to the furnaces. The smokestack, 132 feet in height, is of brick, and this is mentioned because, in later constructions, steel is being used.

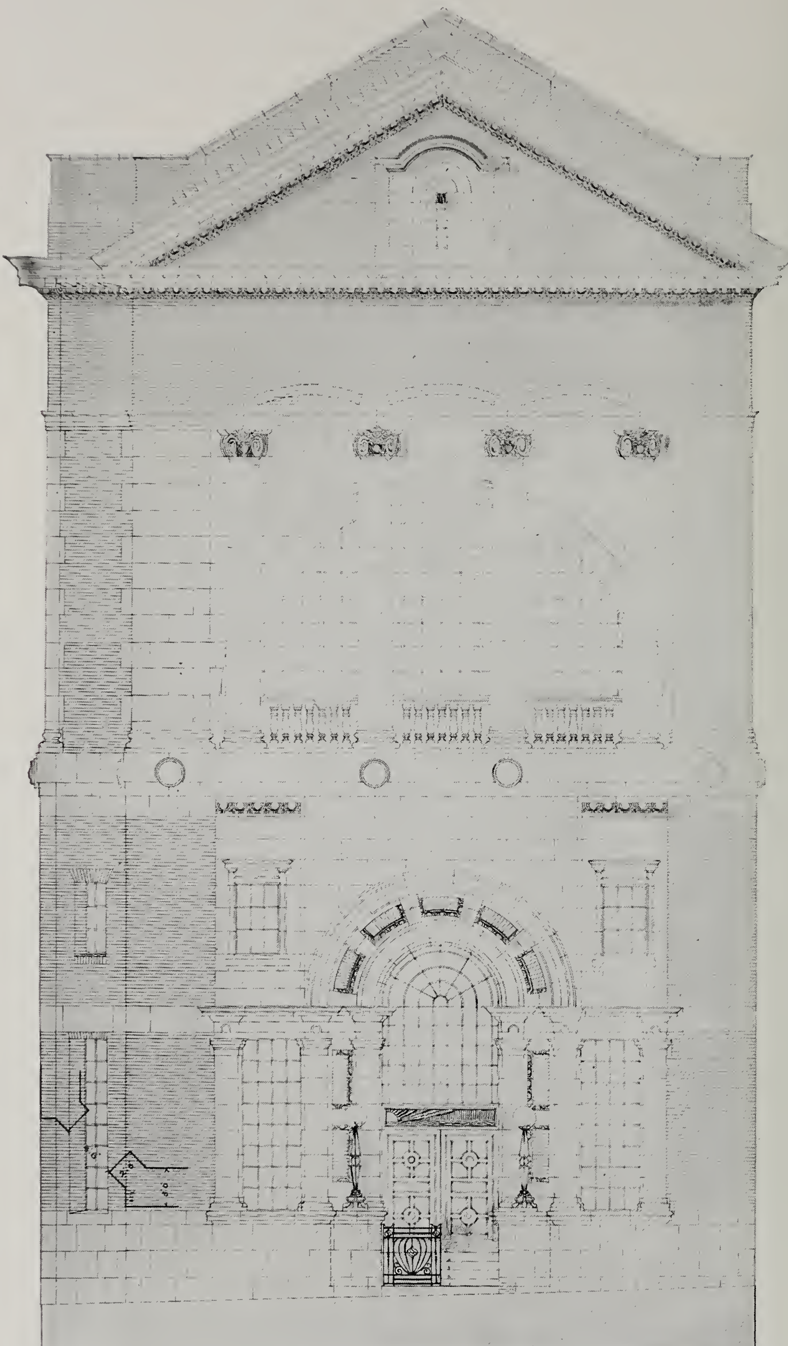
The chief interest centres in the engine house, which measures 110 feet by 52 feet. In the basement all pumping and condensing plant, steam piping, condensers, and other accessories are placed, the principal floor being thus left clear. While space is provided for the addition of a fourth unit, the machinery at present consists of three Reynolds-Corliss horizontal, cross-compound, condensing engines of 400 H. P. each, built by the E. P. Allis Company, of Milwaukee, Wis., U. S. A. These engines are, as already indicated, coupled direct to three-phase alternators, each of 300 K. W. capacity.

The converters employed at this station and at the substation at Newport, Middlesbrough, are of comparatively recent introduction into Great Britain, and have been employed in preference to motor generators on account of their high efficiency and their easy manipulation. They consist of direct-current generators, to the armature winding of which connections are made to a set of three collector rings on the end of the shaft opposite that occupied by the commutator. The same winding thus serves both for the alternating current led into the machine and for the direct current taken out. This system of distribution of electrical power is designed to give the maximum power at any point of the system, on the most economical basis. A 500-volt continuous current, direct from the rotary converters, feeds the lines in Stockton and Thornaby, while the Middlesbrough and Linthorpe sections are fed by current transmitted at 2500 volts to the substation at Newport, and there transformed so that power is delivered into the trolley line at 500 volts.

The feeder cable which transmits the three-phase current at 2500 volts to the substation consists of two three-core cables, in each of which are three conductors of copper suitably insulated, each conductor having an area of 50 square millimetres, or 0.0775 square inches. With this small section it is possible to transmit 300 K. W. with a loss of less than 5 per cent. This method of distribution had reference to the position of the main station, the length of the line, and the regulations of the Board of Trade as to the earth return. The river frontage adjoined property already acquired from the old company, and the site was suitable in every way, while a depot acquired at Newport proved equally convenient as a substation. Half-mile section pillars are placed on the curb, accessible from either side, and contain switches for connecting up or disjoining the sections of trolley wire, so that it is possible to cut out any sec-



FRONT ELEVATION OF THE POWER STATION AT CHISWICK OF THE LONDON UNITED TRAMWAYS, LIMITED



ELEVATION OF THE NEW POWER STATION AT BRISTOL

tion of the trolley line or feeder without interfering with other parts of the system.

A point of interest in the Tees-side tramway is the type of car in use. As a rule, the tramways of Great Britain are of the standard railway gauge of 4 feet 8½ inches, and this is the case at Bristol and on the London United Tramways, while in Dublin the Irish railway gauge of 5 feet 3 inches is in use. But the Middlesbrough and Stockton line is on the gauge of 3 feet 6 inches, and the problem of constructing roomy and commodious vehicles was much more difficult on this restricted dimension. By a careful consideration of the "overhang" permissible, a splendid pattern of car was designed. Each car can carry 60 passengers, 30 inside and 30 outside, being seven more than on the first electric car put on the Dublin-Dalkey line, and sixteen or seventeen more than were carried on the first electric cars at Bristol. By judicious planning, a narrow-gauge line can thus give as much accommodation on each car as a wider line. The use of a larger type of motor car, especially designed for this line, obviated the use of trailers, which are opposed to the accepted principle of modern street railway practice,—to employ as units of service separate cars running at short intervals.

The neighbouring town of Darlington, already named in connection with Mr. G. F. Train, and once associated with Stockton in railway pioneer work, will soon be on a level with its historic neighbour, which rather ran away from it when the new electric tramway was opened in 1898.

The main work in hand in the United Kingdom at present, in the extension of electric traction, is in the western suburbs of London, on lines owned and projected by the London United Tramways, occupying the district extending from Hammersmith to Hounslow and Hampton Wick, on the southern boundary, and from the Central London Electric Railway terminus at Shepherd's Bush to Hanwell and Uxbridge, on the north, amounting, if all that has been proposed should be carried out, to over 40 miles of road line, and practically to 75 miles of track. As regards actual accomplishment, the system already extends (working or under construction) to about 27 miles of route, and 13½ miles are under promotion, embracing a section of main road through the suburb of Ealing now making a gap in the system.

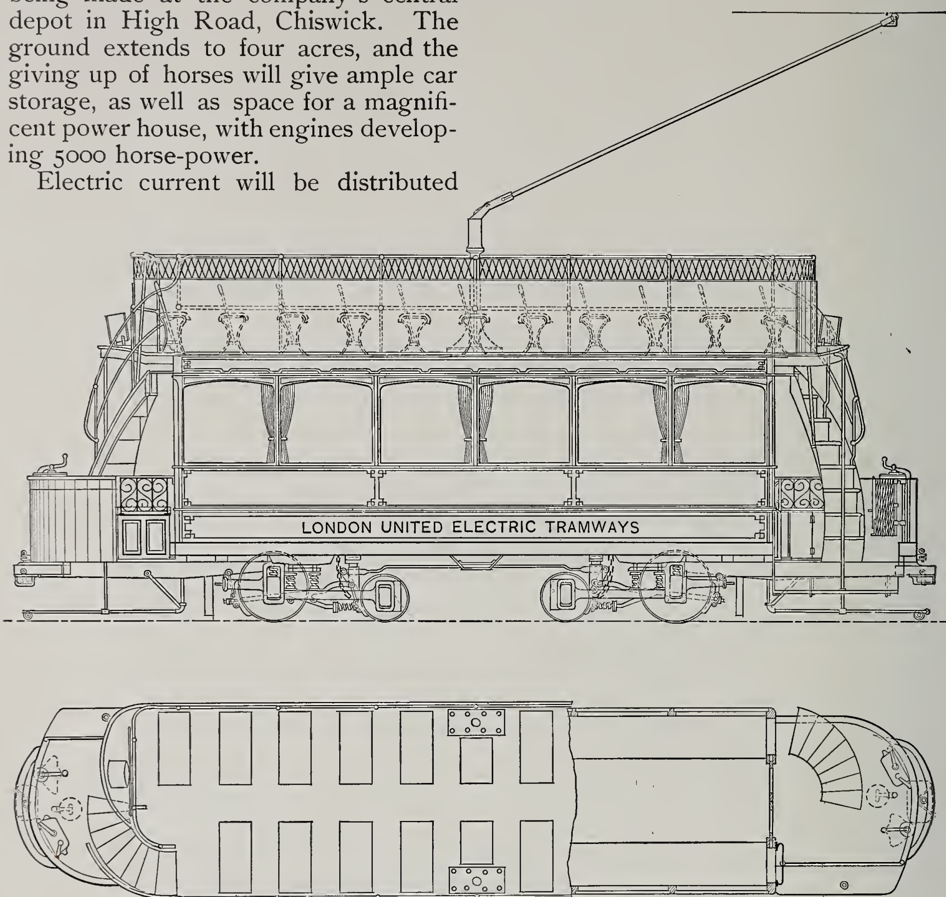
The London United Tramways obtained from the Light Railway Commissioners powers to construct an electric trolley line, extending from their terminus at Hanwell through Southall to Uxbridge,—a distance of a little over 7 miles. Severe opposition was led before the Board of Trade against this Light Railway order being confirmed, the opponents being the Great Western Railway, and Lord Hillingdon, as a frontager and landowner on the route. But this opposition failed, and the extension of the electric system to Uxbridge will soon be an accomplished fact. Although nominally a light railway, it will be worked as part of the general through system of the London United Tramways. Extensions are now being promoted from points on the Hounslow line to bring into direct tramway relation with London the favourite residential suburbs of Twickenham, Teddington, and Hampton Court.

The London United original system, which is thus undergoing the process of extension and reconstruction, is unique in its electrical arrangements. On the representation of the committee of the Royal Society appointed to protect Kew Observatory, the company is debarred from using the rails as an earth return; consequently overhead wires on the double trolley system must be provided, with two trolley poles on each car. The question of allowing the company to use the bonded rail return is, however, under consideration by the Board of Trade. Should this be eventually allowed, the double overhead construction and double trolley poles will, of course, be unnecessary. To secure efficiency, the overhead trolley wires will be connected up on the three-wire system, the two centre wires forming the neutral, and the outside wires the positive and nega-

tive sides. The neutral wire is grounded at the central station only.

For the operation of the electric lines now under construction, and nearing completion, extensive alterations are being made at the company's central depot in High Road, Chiswick. The ground extends to four acres, and the giving up of horses will give ample car storage, as well as space for a magnificent power house, with engines developing 5000 horse-power.

Electric current will be distributed over the company's system by lead-covered paper-insulated cables, drawn into cement-lined wrought-iron pipes laid under the foot-paths. As many as forty-two of these cables will radiate from the station, requiring over a million feet of pipes.



PLAN AND ELEVATION OF A CAR OF THE LONDON UNITED TRAMWAYS, LIMITED

The sections of the line furthest from the centre of the system will be operated from substations, fed from the central power station, the power being transmitted at 5000 volts on the three-phase system. In each substation static transformers will be provided, reducing the current of 5000 volts to approximately 390 volts. Four rotary converters will also be supplied, delivering current at 500 volts, for supplying those sections of the line beyond six miles from the central station at Chiswick.

The rolling stock now building for use over this system will practically be a duplicate of that in use on Tees-side, except that the gauge here is wider. The usefulness of single units of traffic, in the shape of 8-wheel bogie cars, to meet and successfully handle large volumes of traffic, has been most satisfactorily demonstrated at Stockton and Middlesbrough.

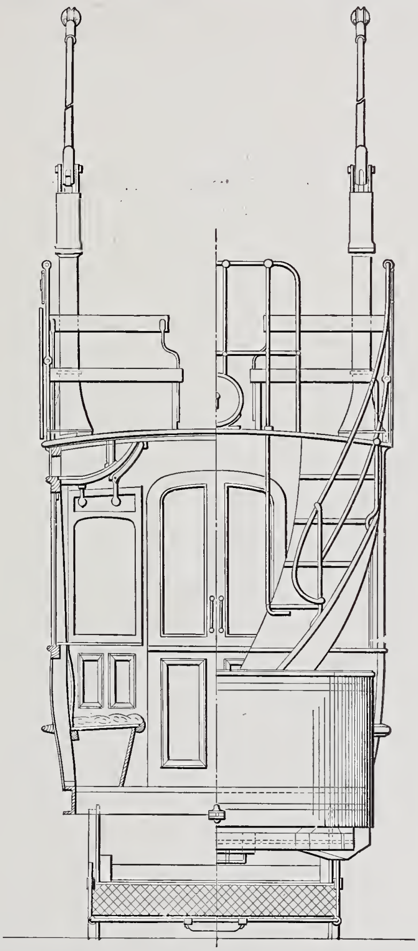
The reference just made to single

units of service in preference to the use of trailers points to some advantages of the electric system. Of these not the least is the introduction of lower fares, a change largely assisted by the use of commodious cars. Those in use on the Tees-side electric tramways were the first cars built in Great Britain to carry as many as 60 passengers, and the same standard is followed in the rolling stock used at, or under order for, Bristol and London. The car, with two motors, and running on two four-wheeled bogie trucks, weighs 6 tons, and with full load will weigh from 10 to 11 tons. The possibility of employing such cars, carrying a maximum number of passengers, thus forms a strong element in the determination of the car fares.

The fare charged is about a halfpenny a mile, the through fare from Norton, at Stockton, to the extreme Middlesbrough terminus being 3d., while a special 1d. fare, irrespective of distance, is granted to workingmen. With those moderate fares, the passengers find superior accommodation in the width, height and general equipment of the cars. And beyond such attractions as cheaper fares and more comfortable cars, there remain two benefits peculiar to electric traction. These are, higher speed and more frequent running, the latter being coupled with a remarkable capacity for extra and special running to meet occasions of pressure.

The cable car must run at the speed of the cable, neither more nor less. But the electric trolley car has splendid elasticity in the matter of running. Its speed can be quickly raised from the lowest to the maximum rate which the local regulations allow. And even where, on selected portions of the route, a speed of 12 miles an hour is permitted, this is absolutely safe, owing to the splendid control over the car which the electric equipment gives. With this full command over the car a higher general average speed can be maintained with electric traction than by any other system. A more frequent service can also economically be given, and on holidays or other occasions where a pressing demand for conveyance arises, the capacity of the system to meet this is limited only by the rapidity with which cars can be sent off.

The operating costs of a well-designed and constructed and efficiently equipped electric tramway have not heretofore been set forth authoritatively in Great Britain. There have been in operation,



AN END ELEVATION AND SECTION, SHOWING THE DOUBLE TROLLEYS

as has been shown in the preceding pages, several overhead electric tramways, in the construction and working of which the highest forms of scientific discovery have received attention. These tramways are the pioneer sections of the Bristol system, the Dublin Southern line, and the Stockton, Middles-

brough and Thornaby tramways. Considerable extensions have been brought into operation at Dublin, and, as described, large works in reconstruction, conversion and extension are going on at Bristol and London. Electric tramways on the overhead system have also been inaugurated at Liverpool and Glasgow. All these (besides lesser schemes in various parts of the country) have served to accumulate a mass of experience, the whole tendency of which has been to confirm what has been urged as to the general adaptability, efficiency and economy of electric traction.

The following figures give actual results drawn from electric lines for the construction and operation of which the writer has been largely responsible. Broadly speaking, it may be said that the cost of operation of a high-class electric line amounts to 5d. per car-mile run. This outlay, divided into its component parts, shows the following results:—

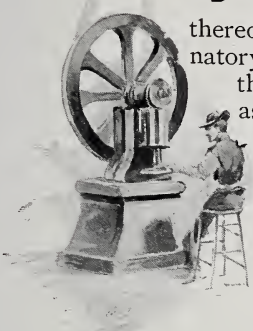
Power House—Engineers' salaries, wages, fuel, etc	0.773d
Traffic Expenses—Wages, uniforms, superintendence, stores, tickets, compensations, etc	2.503
Maintenance and Renewal—Power house, plant, permanent way, line equipment, etc	1.009
Local rates and taxes, etc	0.715
	5.000d

It must be kept in mind that figures of this nature may be much affected by local circumstances. The position of the power house with respect to the line, the price of coal and water, and more, perhaps, than any other thing, the rate of wages prevailing in the district, may materially affect the case.

The quantity of current consumed per car-mile works out to 1.046 Board of Trade unit, and adding the proportion for maintenance and renewal, this is produced at a total cost of 0.903d. per unit, and works out to about 19s., 20d. per car mile. The receipts average 1.311d. per passenger carried throughout the year. A very large increase in the revenue per car mile would entail practically no increase in the working cost, while any additional car-mileage called for by public demand would go to lessen the proportion of cost per mile run. For such additional car traffic, wages and other outdoor maintenance would grow, but the traction cost would remain practically unaffected. This has been shown in the earlier lines referred to, where a higher average per passenger and a higher revenue per mile run have been attained. The point aimed at in operating such lines is to give the public the cheapest and best service, and at the same time to insure that the working expenditure shall not exceed 50 per cent. of the revenue. This result has been nearly approached even in a newly developed line, and in the cases of Bristol and Dublin there have been achieved financial results of a most satisfactory kind, the net revenue yielding a substantial return on the original capital, plus the cost of conversion and re-equipment.

MODERN MACHINE SHOP ECONOMIES

By Oberlin Smith



THAT portion of the above title which follows the first word thereof is certainly self-explanatory, and represents something,—although almost as elusive as a golf-ball,—that many of us are striving to get hold of and control. The word "modern," however, may have many different meanings,—so many, perhaps, as to make a reference to the dictionaries unnecessary, if not hopeless. In mechanical engineering, ancient history often approaches marvellously near to modern current events, and a half century in many cases covers an enormous development from old to new methods. Still nearer to the present day approach the obsolete methods of our predecessors in the profession of electrical engineering, ten years back seeming, in many cases, positively medieval, if not actually ancient.

In the methods and work of the machine shop we may consider a looking backward of fifty years sufficient to show the remarkable changes that have occurred, and to point out as a result the modern economies which we are still seeking to increase. A view of a good machine shop of fifty years ago would show us no machine tools of importance, except lathes, planers, and drill-presses. Many of these lathes were of the old weighted-carriage pattern. They were provided with a power feed for the carriage only, but not for the cross-slide. This feeding was often done with a rough endless chain, but sometimes by a screw which also answered for chasing threads, thereby making it very inaccurate for the latter purpose after being somewhat worn by constant use in ordinary turning, especially in the particular spots which happened to be used the most.

The spindles of these lathes were very small, compared with modern practice; but they will probably seem still smaller a dozen or two years hence, when we shall, doubtless, have become sufficiently educated to use much larger diameters than now. The cross-slides were narrow, short, and lightly built, thus making a very springy relationship between the tool and the work. This involuntary elasticity, so to speak, was aggravated by lightly built carriages with short bearing surfaces upon the "vees" of the bed. The vees themselves were so low and narrow as to wear rapidly, the carriage thus scooping a hollow place at the part of the bed most used, and in the case of nearly all lathes, with short work being performed most frequently, the outer end of the bed often was comparatively unworn. The bed itself was always built as lightly as possible, with an elaborate ribbed construction which seemed entirely unfitted to withstand the vibratory stresses brought upon it while performing its natural functions.

The planers of that ancient day suffered from the same faults, in general, as did the lathes, except that there was no question of inaccurate thread-chasing, nor any chance for making an important work-supporting member abnormally light, as is so easily done in the case of lathe-spindles. Those planers, however, appeared to be framed as flimsily as possible all over, the saving of cast iron seeming to be the primary object in the minds of the designers. Compared with modern planers, the old

machines had but small driving power, and the arrangements for belt-shifting were so crude as to make them very jerky at each end of the stroke. They were usually built with a power cross-feed, but the vertical feeding, as well as the vertical adjustment of the cross-rail was generally performed by hand.

The right and left screws used for this latter adjustment were often chased inaccurately as regards pitch, so that the two ends of the cross-rail went up by jerks, so to speak, with a consequent lack of parallelism between this important member and the top surface of the table. The latter was generally made so thin as to be pulled out of flat by the clamping of the work to it, thus giving it, if it happened to be twisted, a rocking motion, or, in any case, a lack of harmony with the imaginary plane in which it was supposed to move. The cross-feed was so arranged that but a very narrow cut could be taken, even when of shallow depth for finishing, thus entailing much waste of time, and excessive wear of the tool by much travelling, in comparison with the modern method of making a finishing cut shallow and very wide.

The drilling machines of those days were also extremely crude. When not attached to a shaky wooden ceiling or wall, with the work lying on the floor, they often consisted of an independent machine, made with two wooden or iron columns having the drill-spindle between them, fed by a slippery hand-wheel directly surrounding the spindle. This moved with deliberative reluctance, so much so that it sometimes took nearly as long to return the clumsy structure to its upper position, carrying the weight of an unbalanced spindle for a burden, as it did to force the drill down into the work. Some improvements had at this time been made in the way of regular drill-presses, foreshadowing the designs of the present time, having a single iron column, parallel to, and some distance from, the spindle. Such few twist-drills as were used were forged by the blacksmith; but the great majority of drills were of the old-fashioned flat type, with a very short bearing in the work, thus rendering it difficult to drill holes of reasonable straightness, especially with the small, springy, loose spindles generally used. The hand-grinding and careful measuring of the diameter and length of lip of each drill was something which required much skill, and a wearying amount of time.

Another machine tool which should have been included in the category of the three principal ones above mentioned was the shop grindstone. Usually this was mounted in a wooden frame, with or without a water-box beneath it. It always wabbled, or nearly always. It ran very slowly. It was very wet, at least the enveloping atmosphere was.

The hand tools of the old shops in question were, as far as they went, not so very different from modern ones. Straight-edges, squares, measuring rules, and other instruments of precision were, of course, not nearly so precise as now, and surface-plates were not in common use, nor was, to much extent, the system of fitting working surfaces together by scraping. Taps and reamers were much the same as now, except not so accurate, nor so easy-working; neither was the adjustable idea in regard to reamers, or mandrels, developed to any considerable extent. Centre-punches, chisels, hammers, files, and so forth, were much like those of the present day. The laying out of work was done mostly by hand, and often by crude methods, in marked contrast to our present system of scribe-blocks, templates, jigs, and other devices. Chalk and string were freely used, as were pine blocks for filling up holes, so that the laying out of lines could be done upon temporary surfaces.

Of power-generating machinery it is hardly worth while to speak in detail. We all know the old water-wheels, the old-fashioned boilers and engines. Some of them are with us yet. Power transmission was much more primitive than now, by reason of rigid and non-adjustable hanger boxes, keyed-on pulleys, slow-running shafts, and gummed-up, dawdling belts.

In general, the three classes of ma-

chine tools mentioned had begun to have considerable engineering thought devoted to them, and had become independent machines especially adapted to the functions they were to perform. They were fairly good prototypes of modern designs, these having really not been very much altered in general principles from the early ones in question, the much greater efficiency now existent having been attained mostly by improvement in details, and a great increase in strength and stiffness.

The æsthetic element in the early tools in question was not neglected, that is, as far as the artistic feelings of the designers were concerned. Although they tried to save as much iron as possible, their regard for high art induced them, in many cases, to add additional metal in the way of mouldings, fluted-work, and gothic tracery. Especially was this manifested upon the poor planing machines, where the large, flat surfaces of the columns allowed room for architectural imitations of considerable vertical magnitude. In some instances a machine frame was copied from a grape-arbour, vine, grapes and all. Then, when the sculptor and carver had exhausted their powers, the fresco-painter appeared and imitated the rainbow in all its glory.

The objectionable part of these early tools, however, from a practical point of view, was their springiness. Strength, combined with abundant rigidity and inertia, is obviously what is required in machine tools above all other classes of mechanical apparatus, unless, indeed, it may be astronomical telescopes.

So much for the non-economies of the old system. The new system is a creature of gradual development for the last half-century or so. Its evolution is not yet complete, by any means, but enough has been done to make the products of the machine shop vastly cheaper, as well as more accurate. These products, scattered throughout the world, in the form of every conceivable kind of apparatus connected with industrial civilisation, have been some of the chief factors of that civilisation itself. Not only is the shop of to-day making machines, but it makes machines to make machines, even to the second and third generation, so to speak.

Reviewing, first, the modern improvements in the standard machines referred to in the beginning of this article, we find them all vastly more rigid, durable and convenient than were the tools of the olden time, although there is much yet to be done in enlarging spindles and other parts carrying work to be operated on, and in adding more metal to the frame-work and other stationary or slowly-moving parts where this can be done without making them too clumsy and inconvenient of manipulation. We shall, doubtless, yet learn that cheapness will be secured in the end by the expenditure of more money in material, in places where it can be properly put, simply to get the dead weight, and consequent inertia, so useful in preventing harmful vibrations and elastic distortions.

Among other improved details in lathes, we see more powerful belts, longer and wider carriage and cross-slide bearings, larger diameters for spindles, rod-feeds, screws for screw-cutting only, and quick-acting devices for change-gearing. In planers, we see far more accuracy in regard to flatness and squareness in general, truer pitch of screws, much coarser feeds, quicker reversing apparatus, power vertical feeds and adjustments, and, better than all, much greater strength and rigidity in all parts. In drill-presses, we see balanced spindles and heads, quick spindle-returning devices, larger spindles, more powerful driving gears, and heavier and more rigid frames. When we use grindstones, we see that they are kept carefully trued up. They run in well-designed iron casings and rise to the dignity of actual machines. Much of the grinding work is, however, now done with special emery-grinding devices.

In hand tools, there is a variety of new conveniences, too numerous to mention. Not only have we added many new measuring instruments, such as micrometers, for example, but also special cutting tools and laying-out tools

of various kinds. Moreover, we have vastly changed our standards of measurement, working now in thousandths or ten-thousandths of an inch, where formerly we worked in eighths and sixteenths.

In the matter of repairs to these tools, we now have them replaced by the maker, or ground to their original shape in special repairing machines, rather than by sending "the boys" to the blacksmith shop to await their turn with one another while the blacksmith slowly hammered and hardened and tempered the turning-tools and drills to shapes which his fancy dictated at that particular time. Such tools as are repaired in the modern tool-room are usually fitted to gauges to give them uniformity, and are often ground to shape automatically.

Aside, however, from the great improvements that have taken place in the design of old-fashioned tools, for many of which credit must be given to British makers, who have led others by their example to the building of heavy box-frames, without architectural ornaments, and to that general clumsiness, as it may be termed, which is so conducive to strength and rigidity, modern shops show a splendid development in the use of several new classes of tools, which may be termed regular, semi-special, and special. The last two mentioned are particularly adapted to the work which they are to do, rather than to all things and everything.

Among the additions to the class of regular, conventional tools are the shaper, in its various forms; the vertical slotter, and its brother, the key-seater; the horizontal boring machine; the vertical boring lathe, as it should be called; the milling machine in its different varieties; and the grinding lathe, grinding planer, and various tool-room grinders for twist-drills, cutters, and reamers. There are also various modifications of standard tools, such as the one-post planer, the combination miller and borer, and others.

Among semi-special machines may be mentioned, first, and as of almost transcendent importance, the turret-lathe, with its various modifications, such as screw machines and turret-drillers. Other tools of this class may be found in double-headed and double-carriage lathes, planers with additional heads, multi-spindle drilling machines, presses for cutting, drawing and forming sheet and bar-metals, etc.

Among special tools, constituting the most important means of developing many of the great industries, where millions of small articles are made in duplicate at a fraction of the cost formerly incurred, may be mentioned gauges, templates, jigs, and cradles. In connection with these are many special machines for turning, spinning, drilling, boring, milling and grinding, each of which is made to perform its work upon the paritcular piece of the product manufactured while being useless for all other purposes. Their speed of production is, in many cases, almost marvellous. A good instance of such a machine is found in the United States in a special driller which is used to bore all the holes simultaneously in a mowing-machine frame, together with all the tapping and facing, with the result that these frames are each completed from the rough casting with cheap labour, one attendant serving several machines at a time, in as few minutes as it would take hours by ordinary machines, with a good workman at each. They are, moreover, all exactly alike, within certain minute limitations of "tolerance," so called, and are practically interchangeable.

The importance to the industries of the world of the duplication of similar parts on the interchangeable system, by these modern methods of manufacture, is too well known to need further comment here. By such methods cheap, unskilled labour can perform vastly better work than can the most skilled mechanics by the almost infinitely slower methods in former use, where general, instead of special, tools were employed.

It is true that the old shops of fifty years ago are not all dead yet,—more's the pity. Furthermore, even in comparatively good shops, we see some ancient tools that are not defunct, but should be. Taking a general view,

however, of the ideal and often real, machine shop of to-day, we find handsome and roomy buildings, with abundant lighting, heating and ventilation; with clean ceilings and walls, and floors arranged in orderly fashion. We see steam-power (if such be used) generated with a small fraction of the fuel formerly consumed, driving quick-running shafting mounted in roller bearings and adjustable hangers, carrying light, true pulleys, easily interchangeable, operating narrow, quick-running belts and supplying abundant power to the tools below.

Or, as a better alternative, we see these tools arranged regardless of the straight rows and constrained positions due to the shafting system, and driven by individual electric motors fed by concealed wires leading from below the floor, the overhead space being left entirely clear for light, air, safety and beauty, while giving room for improved electric hoisting apparatus of various kinds.

With either of the above systems (the last mentioned happily looming up in the ascendant) we see clean, attractive, intelligent workmen running cutting tools at much higher speeds than formerly, often with special lubricants, using all the improved machines, semi-special and special, which can be adapted to the particular work in hand, all with a resulting output not dreamed of even less than a generation ago.

This rather meagre survey merely hints at some of the economies already existing. There are many others to follow, and these will be brought about during the coming years by the inventive talent of mechanical engineers, who, happily, are now being educated not only in colleges, but in severe shop-practice as well.

It is probable that these improvements will follow chiefly the lines of simplified design and construction of product, more special tools, better and faster cutting methods, better architectural and power transmitting shop arrangements, more extended use of electricity for driving, doubtless leading eventually to the total abandonment of belting and shafting, and, last but not least, more harmonious and conciliatory arrangements between employers and employees, in office, in draughting-room or in shop.

This will doubtless be brought about by further "combination" on both sides, with boards of conciliation, managed by both parties, to settle upon mutually satisfactory conditions, thus conducing to the intellectual, moral and financial happiness of all concerned. The importance of a contented, yet ambitious, *personnel*, in addition to a *materiel* which is mechanically above reproach, cannot be too strongly impressed upon all those earnest souls who are making the machine shop economies of to-day,—and of the days to come.

THE MODERN FOUNDRY

By Joseph Horner

THERE are two aspects in which foundry work may be regarded:—that which relates to the mechanical details of the various departments of moulding, and that which concerns the laying out, equipment, general arrangement, and management. It is proposed to consider the latter only in this article.

The belief that the foundry is the least progressive department of the engineer's factory is one which is very common, and one that appears to be well founded, corresponding with a general rule, to which there are the usual exceptions. But those exceptions are becoming numerous in recent years. There must be reasons for the comparative neglect of this department amidst the general reorganisation of factory methods,—the most prominent being those which relate to the machine shop,—that has been going on during recent years, and it will be well to state briefly the nature of those reasons.

The principal cause probably lies in the want of uniformity in the work which is done in most foundries. The volume of general and jobbing work almost always predominates in the average foundry over that of a repetitive character. The relations between these kinds, however, vary widely in different shops. Specialisation, moreover, has increased much of late years; yet in many foundries the methods which are best suited to specialisation have not been developed as they might have been. Neither have the general shops been equipped with due regard to such economies as have been easy of attainment. The present, therefore, is handicapped by the traditions and practice of the past.

Another reason, perhaps, for this conservative practice lies in the difficulty and cost of introducing a better system into a foundry, the adaptability of which to that shop is not always apparent. Foundry work, again, is so much unlike that of the other departments that many employers and managers know very little about it, and are afraid to meddle much with it. Moulding is a dirty trade, and few employers have gone through its routine as they have through the other shops and offices. There is, therefore, still much charlatanism in this department. Purchases are effected, and arrangements adopted without special knowledge, and the moulder is blamed if appliances and materials do not fulfil expectations. Employers who would see the folly of attempting to equip all machine shops alike will commit the error of fitting up a foundry in such and such a way because some one else has one equipped in that manner.

The result is that many existing foundries reflect no credit on the wealthy firms who own them, being ill lighted, ill ventilated, cold and hot by turns, destitute of labour-saving arrangements, and ill supplied with suitable appliances generally. Or, on the other hand, they have been fitted up at great expense with appliances which are not adapted to the character of the work. Then blame is thrown on the foremen and moulders as an unprogressive, ignorant set. To such firms reform will come only under the severe pressure of outside competition, which will render necessary the mending or the ending of the business. When laying out a new foun-

dry the designer is confronted with many problems which are not easily solved. A common formula is utterly impossible. Each individual case must be studied and resolved on its own merits. To mention a few alternatives is the best way to state the difficulty. Which is the best method of transposition,—rails laid down for trolleys, or flat plates, or overhead trolley tracks? How is a general solution possible? Again, what proportion should overhead travellers bear to swing cranes? Some would swear by the first, others by the last. Then as regards motive power, should this be steam, electricity, or compressed air, and, if this is settled, which particular system of the many offered is preferable? In reference to methods of doing work, at what stage shall hand work be displaced by machine work; and if the latter is decided on, what machines, and what operating agents are best? Outside of these mechanical problems lie those which deal with the working arrangements of the shop, the best location of stores, the extent to which subdivision of labour shall be carried, and much besides.

It is clear, therefore, that there is but one course open to the foundry designer, and that is to thoroughly gauge the requirements of a given works, the average weekly tonnage, the character of the castings to be made,—whether light or heavy,—the proportion of green sand to loam, the proportion of core making, including whatever relates to these matters; and last, though not least, the probable extent of future expansion. Then, having a grip on these, the coat must be cut according to the cloth, and the foundry designed to fulfil these conditions as far as the governing limitations will permit it. The idea of the writer is that when a firm finds itself cramped in space by surrounding buildings, it would generally be better to remove bodily right away to suburbs, and establish a nucleus there for extended premises.

The most important matters which have to be settled in the planning of a new foundry, or in the reorganisation

SAND MIXING ROOM IN THE FOUNDRY OF MESSRS. SULZER BROTHERS, WINTERTHUR, SWITZERLAND

A FOUNDRY FLASK CONVEYOR. INSTALLED BY THE LINK-BELT ENGINEERING COMPANY, PHILADELPHIA

of an old one, may be conveniently classed under four principal heads:—1. The general shop arrangements. 2. The means of hoisting and hauling. 3. The aids to actual moulding. 4. The melting of metal, fettling, means of testing, and other details, each of which has to be carefully considered in relation to any particular class of circumstances. Considering these in order, let us take,—

1.—The general shop arrangements. Designing a new foundry building is a source of anxiety. It is one of those things for which no hard-and-fast rule can be laid down, since every case must stand alone, governed by its own set of conditions. But the following remarks will be generally applicable:—

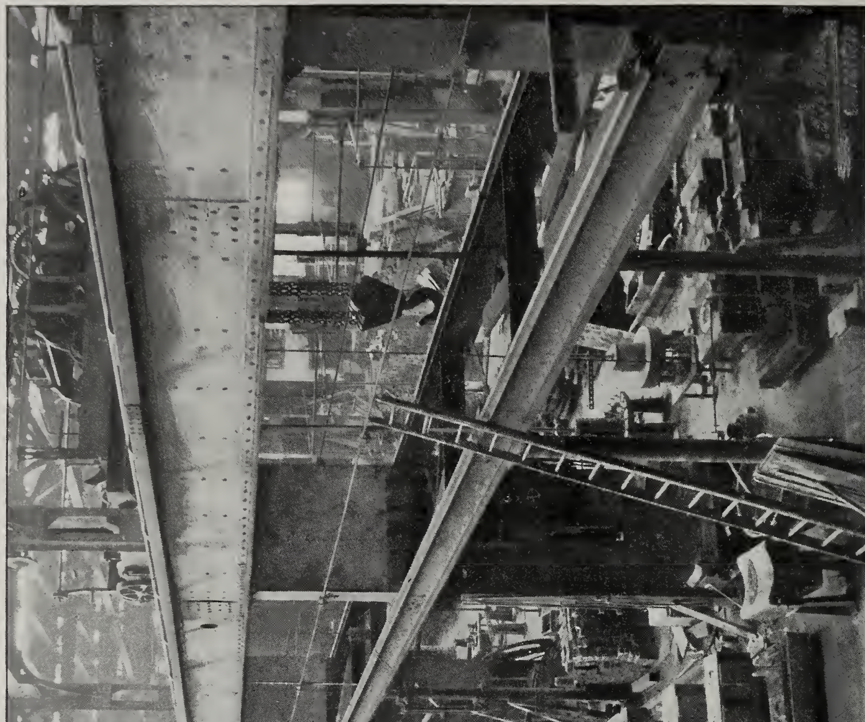
The use of timber should be avoided. To build a foundry with roof principals of timber is to invite a fire,—a serious affair, because it not only ruins machinery, but throws the work behind. Other enemies to the work of the foundry are rain and snow. If these come in, they ruin moulds. Many foundries suffer from leaky roofs, so that in the winter the moulders have to dodge miniature lakes which dot the floor. Another point is stability. A foundry is almost more than any other shop strained by the continual operations of the numerous hoisting machines with which it is equipped.

Either a brick or a steel building will fulfil the conditions required. The writer's idea of a modern foundry is a steel building, roofed with slates. The reason for preferring steel is its lightness, its immunity from fire, and the economy of space which it affords. If steel columns are used throughout, they can be made strong enough to sustain the roof without any assistance derived from walls. Thick walls of brick occupy 18 inches or 24 inches of space, while with steel columns a single or double row of bricks is sufficient for filling in. Further, if a stout brick wall is built, either abutments or separate columns are required to carry the swing cranes, which can be attached directly to main steel columns. The tops of steel columns serve excellently to carry the rails or runways for the travelling cranes, being better than corbels, and as good as brick abutments. Since a foundry built in this way 'is fireproof, there will be no need to insure it, and the annual premiums saved may be devoted to improvements and additions.

Slates are best for the roof, secured to the purlins with copper nails. Neither corrugated iron, nor galvanised nails are suitable for foundry roofs, because they become injured by the gases from below, and cause leaks in the course of time. A well-laid slate roof, though expensive, is nearly everlasting. A thin layer of cement may be put between the slates and the purlins to assist in making the roof watertight.

Many foundries are too dark. There is no shop where light is of more account,—witness the necessity for the constant use of hand lamps in day time to illuminate deep moulds. The roof should have a deep lantern, with windows made to swing for ventilation, and the side walls should have large windows. With steel columns entirely supporting the roof, the walls may be nearly "all windows."

The laying out of a shop is often governed by such conditions as the contiguity of other buildings, area available, the ground plan, or by the necessity for utilising existing buildings. The arrangements, therefore, of foundries must needs differ with the conditions imposed by circumstances. It is not always a question of what is best, but what is possible. But always one point should be borne in mind,—the endeavour to so arrange details that undue handling of flasks, pig, scrap, coke, castings, etc., shall be avoided. The ideal foundry is the one in which nothing goes over the same ground twice, but where the raw materials come in at one end, or at one side, and the fettled castings go out at the other. Cranes, and trolley tracks also, should be set in such localities that labour shall be lessened as far as practicable. The heaviest work should be done at the place to which materials and flasks can be taken with the least hauling, and from which the castings can



THE LOAM FOUNDRY OF MESSRS. SULZER BROTHERS, WINTERTHUR, SWITZERLAND

be taken most readily out of the shop. If a new building is to be erected, walls and gantry should run parallel from end to end. If two such bays are required, one may be narrower than the other, for the lighter work. If such a design cannot be adopted, then the endeavour must be to separate different classes of work as much as possible in one, or in several shops, suitably connected, and to arrange hoisting appliances accordingly.

A clear central floor area, served by an overhead traveller, or travellers, which, by longitudinal and transverse movements, will cover the whole area, is most desirable. A single building of this kind will frequently serve very well for the whole of the work of a foundry, heavy and light, loam, and green sand, core making, and machine moulding. It is sometimes convenient to erect subsidiary buildings adjacent to, and connected with, the main one, for one particular branch of work, as for small core making, or for the making of small castings for some special machinery. But there is little advantage to be gained in such arrangements. They are often necessary outcomes of growth. With the exception of the brass shop, which is properly kept distinct, there is no reason why the whole of the work done in a foundry, however large, should not be performed under one roof, divided into bays. This arrangement saves much hauling about of stuff, concentrates everything within the grasp of the foundry manager, and is a source of economy in the preparation of the materials, and in the carrying through of the work.

The location of the plant about a foundry is a matter of convenience rather than of any hard-and-fast rule of procedure, provided the floor space is kept clear. The cupolas are often within, and often without the building, the spouts then coming inside. Moulding machines should be ranged in line. Core stoves should be wholly outside, and fired outside, the doors only opening into the foundry. Sand bins should be placed at intervals without, and served by tracks; or within, at the sides. The loam work ought preferably to be done at one end, because the casting pit, or pits, will then be least in the way of other work. The heavy core work and the core stoves are best located along with the loam work. Where the volume of loam and core making done is large, an entire bay may be laid out for it. Suitable rail tracks down and about the shop, with turntables, are desirable for the transit of work, flasks, etc. The heavier flasks, core plates, and rings should be kept outside, covered by a traveller, which would drop them down at the door of the shop, to be taken up inside. It is convenient to make piles of many small and often-used flasks within the shop, against the wall, or have them neatly piled out on the floor, provided they do not interfere with work.

2.—In the matter of hoisting and hauling, there is scope for much diversity in practice. That which is suitable for a foundry, casting, say, 150 tons a week, is not so suitable for one doing 20 or 30 tons only. That which is adapted for a shop turning out heavy castings only, is not required in a shop engaged exclusively in light work.

The problem of hoisting machinery generally causes more anxious deliberation in reference to the foundry than to any other department of the establishment. The reason is to be found in the fact that the work is of so varied a character and the separate lifts required are so numerous. The larger the shop, the more complicated the problem becomes. In order to understand the conditions which have to be fulfilled, it will be well to note the various classes of work which must be provided for. These include the haulage of metal and of flasks about the shops, the pouring of metal, turning over of moulds, the lifting of copes, the withdrawal of patterns, the setting of heavy cores, and the knocking out of castings. In each case there is a range in weight from the maximum to the minimum.

Many of these operations will be going on simultaneously in various parts of the foundry; some will occupy a few seconds, or minutes only; others may

take half an hour. Some can be performed with rapidity; others, such as the setting of cores, the lifting of copes, the withdrawal of patterns, and the turning over of flasks, must be performed with the utmost steadiness, moulds being often partially fractured, and cores dislodged in consequence of lack of steadiness in the hoisting tackle.

A CORE OVEN. MADE BY THE MILLETT CORE OVEN CO., BRIGHTWOOD, MASS.

There is no single type of hoisting machine which will fulfil all these conditions in a foundry. The following remarks will indicate what, in the writer's opinion, is the most suitable general arrangement, the details of which must, of course, be modified to suit different shop dimensions and classes of work done.

The best arrangement is that which combines provision for the lifting and transit of the heaviest loads down the shop, with the manipulation of the lighter work in all parts without any delay. These conditions are best fulfilled by the use of a power traveller, or travellers, supplemented by small jib cranes of light capacity pivoted next the walls, or against columns, and these should cover most of the shop area.

Hand travellers are practically useless in long foundries, though they are serviceable in small ones. The choice, then, lies between those which are operated by steam, rope, or electricity. The present period is one of transition. Steam travellers are objectionable in any shop, the least objectionable form being that in which the boiler and engines are placed at one end, traversing a jenny, instead of being on a crab or trolley, and moving with it. The square shaft type of traveller is, at the best, a wasteful and rather antiquated mode of transmission. The cotton rope drive is better; but this, like the square shaft type, is open to the objection of running all the time and absorbing power, whether in use or not. The electrical type is, on the whole, the best. The objection to its employment in foundries by reason of the injurious effect of dust on the motors, is met by the use of iron-clad motors.

The travelling speed of many cranes is too slow for the requirements of long foundries, not so much in the travelling or traversing when loaded, but in the travelling when empty. In a long shop the saving of time between a slow and a rapid rate of travel would amount to a good deal. The question of speed for travelling is of great importance, moreover, in relation to the use of small cranes. The traveller will often be fixed

A VIEW IN THE FOUNDRY OF THE ATLAS ENGINE WORKS, INDIANAPOLIS, IND., U. S. A.

with a job for a considerable length of time, often for twenty or thirty minutes or more, due not only to the time occupied in actual haulage, but also to that spent in slinging, making adjustments, in drawing a pattern, in getting out and transporting a casting, in turning over a box, etc. During these periods the light cranes are of service. But it is obvious that whatever gain is obtained in travelling speed tends to lessen the time in which a traveller is fixed, and as a result renders a smaller number of fixed cranes necessary.

In American foundries there are additional rivals in several types of hoist, which are so valuable that they must be noticed in any remarks which relate to lifting tackle. The hoists are of three classes:—the pneumatic, the hydro-pneumatic, and the steam-hydraulic. Each possesses the advantages of being light, handy, destitute of toothed gearing, quiet, and capable of very precise regulation. In the pneumatic and hydro-pneumatic hoists the use of a compressor plant is essential. This is not objectionable when such a plant is already laid down, or is in contemplation for other purposes, but it would probably militate against the employment of the air hoists in small foundries. In some of the steam-hydraulic cranes an existing steam boiler can be utilised.

Excepting in the respect of the source of power, the systems have certain broad resemblances to hydraulic methods, inasmuch as a cylinder is used in each case for the purpose of hoisting and lowering, either directly, or through multiplying pulleys. In the working out of the systems there is much individuality, and difference in arrangement and detail, so that the hoists cover the whole range of requirements demanded of light foundry cranes. They cost little, and can be multiplied so that men do not have to wait for the traveller or

for the crane, as is often the case in foundries. An electrical or a cotton rope traveller is necessary in almost every foundry, but its value is limited. It cannot be serving all the hands who may require it at one time, and supplementary cranes are, therefore, handy.

3.—We now consider the aids to the actual moulding. It is in the methods of turning out work that chief interest centres, the questions which arise for solution being mainly concerning division of tasks, and the relative economies of unaided hand moulding, or the use of machines.

The work of the complete foundry includes the following classes:—General and special work; green sand, light and heavy; dry sand, and loam, light and heavy; machine moulding; core making. The more these are separated and each class subdivided, with corresponding division of tasks, the greater will be the resulting economy. To consider each of these in order and in detail is impossible here. The following remarks will, therefore, have reference mainly to the foundry as a whole.

In many modern foundries moulding machines are an important part of the equipment. These, in American establishments, far outnumber those in British ones. By their aid unskilled hands regularly perform tasks equivalent to those of skilled moulders, and even perform them better and vastly cheaper, so that three advantages are gained,—economy in time, economy in wages, and an improved product.

But even in moulding machines there are immense differences, and certainly the last effort has not been made yet in this direction. They are as highly specialised and subject to as great variations as any single engineers' machine tool. Even heavy castings do not now lie outside their sphere of operations, nor do those of considerable depth. If work is of a sufficiently repetitive character a machine can be selected or devised for it. Hand ramming, ramming by steam, and by compressed air and by water all give good results under different conditions, and one cannot be said in general to be better than the other. Theoretical objections to any one of these can be urged, but the sole test is practice, and in practice they are all working successfully. Several firms now make moulding machines of portable types, light machines mounted on plain wheels. Some are of narrow gauge, sand furrows being laid alongside,—others of broad gauge, with the sand underneath.

The most complete installation of moulding machines is that in which there is no handling of sand, and in which the moulds are cored and closed by men other than the moulders. This method is adopted in many shops. In the most perfect systems the work is not done adjacent to the machines, and the flasks are not even taken away by hand. In short, the early methods of machine moulding,—just an advance on the plain plate moulding,—bear about the same relation to the later methods that hand work did to the early machine work.

It may seem invidious to select any for special mention when there are numerous really good types. With this disclaimer, note may be made of three,—the Pridmore, Adams, and the Tabor. Each is almost a type in itself. The Pridmore, instead of being fixed, goes to the work,—a point worth consideration. In the Tabor machines,—air operated,—the sand is rammed by the air pressure over the pattern, and the platen is lifted by air. Even the dry brush is dispensed with, for a flexible air pipe is used to blow the sand from the pattern. The latest development in machine moulding is the multiple, introduced on the Farwell machines of the Adams Company. It saves the labour of pouring a large number of single moulds, and economises floor space. The latter is just as important as the former, because when a floor is being covered with moulds, at the rate of, say, nearly one a minute, it soon becomes full. In the multiple system a pile of moulds is made, each section of which, except the top and bottom, have moulds made on each side. One ingate passes from top to bottom. The metal then falls to the bottom, filling the lower

portion before it runs off into the upper moulds. In practice, the hydrostatic pressure does not produce swelled castings in the bottom, because the metal in the runners becomes congealed before the full pressure comes upon them. The limit to the height is set by convenience of pouring and by the pressure on the bottom sand. Multiple moulds of from seven to ten in number are the maximum desirable.

Rapping is one of the greatest obstacles to obtaining uniformity in the dimensions of castings moulded from the same pattern. It is always an uncertain quantity in the hands of different moulders, each man being a law unto himself in this matter. But the loosening of the sand, or else the use of a stripping plate, is essential in order to secure the clean delivery of a pattern. This is, in a large degree, one reason why moulding machines are growing in favour. Reliance can be placed on the uniformity in dimensions of the moulds made with them. In many, stripping plates are used; in some, rapping alone for ordinary work is relied on.

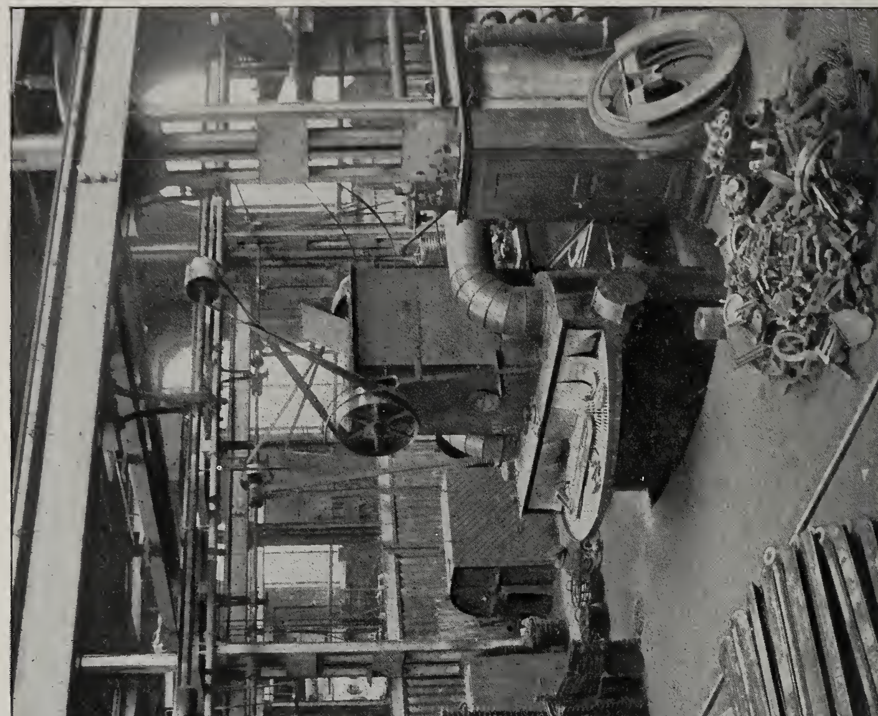
In shops doing a general run of work only moulding machines would not conduce to economy. For these are expensive, not in first cost, but in the extra expense entailed in the preparation of the patterns, which can be recouped with profit only by a large volume of repetitive work, and because men have to be trained specially to operate the machines. If the work on these slackens, the men are not of much use for ordinary moulding. It is necessary, therefore, to success in this direction that a shop shall have a good run of standard repetitive work, and that it shall get into the system of doing it on machines. Pattern makers and moulders alike have to be trained before the best results are possible. In some shops most of the work can be moulded by machine; in other shops little or none is economically possible.

The foundry of a prominent firm of air-brake manufacturers affords one of the most instructive studies in modern foundry economies, in which machine moulding has a large share. The firm has an immense run in specialties which lend themselves to such economies. Practically all the work is machine moulded, and the cupolas are running all day, the tapping and slag holes being open continuously. In this foundry an elaborate system of conveyors for sand and for flasks is installed. Briefly, this minutely subdivided system is as follows:—

In making air-brake cylinders and reservoirs the machines are worked in pairs, one on the cope, the other on the drag. A sand conveyor overhead runs along the shop, and each machine is fed from it by a chute, which is opened and closed at pleasure. As the moulds are completed they are lifted from the machines by hydraulic jib cranes and placed on the flask conveyor, which carries them along about thirty feet to the core setters. Some cores are set by moulders, others by unskilled labourers. Then the conveyor carries the cored moulds onwards to another set of men, who clamp them. By this time they have arrived at the rear of the cupola, where another set of men pour; from there the moulds are carried on to the fitting department. The sand shaken from the castings is wetted, and new sand is added, and screened, and elevated to the overhead conveyor, to be carried along again to the machines.

Of course, everything is so regulated that no time is lost in waiting. Everything proceeds with rhythmic precision. The shops are built and equipped to do one class of work mainly, and it is searcely astonishing that four machines will turn out 300 cylinders and 400 reservoirs in a day, or that two machines will turn out from nine to twelve hundred moulds of light castings in a day.

4.—The melting of metal has not yet been placed on an entirely scientific basis in modern foundries, although it is better understood now than formerly. The foundry cupola has long been a source of waste. Yet results obtained depend, in a large degree, on the experience of the melter, and on the nature of the work, and so we find cases in which cupolas of antiquated type are working with fair economy. But the



CLEANING ROOM IN THE SULZER FOUNDRY, SHOWING MACHINES FOR FETTLING SMALL CASTINGS BY SAND BLAST

ime is rapidly passing when so much will be left to chance and luck. A modern cupola is designed and constructed on a scientific basis, and the home-made ones must disappear. There is as much need for experience in these designs as in that of a machine tool. Their construction, therefore, is becoming a specialty of a very few firms.

American founders have gone more fully during recent years into the question of cupola design than those in Great Britain. One reason seems to be their pre-eminence in the manufacture of very light cast iron articles, in which a high quality has to be maintained at a low relative cost. Stove work, agricultural work, pipe fittings, railway castings, malleable castings, and a keen competition render good grading and economical iron melting a necessity.

The principal interest in a cupola centres around the tuyeres. Modified in dozens of ways, patented, and repatented, yet the bottom fact, beside which all else are minor details, is the addition of an upper row of tuyeres, by which the ascending gases are made to yield up a portion of heat which would otherwise be lost.

The vexed question of fans *vs.* blowers is too wide for treatment here. The only point which need be touched on is that results very much depend on conditions. There are badly made fans,—fans that are noisy and fans that are noiseless; blowers that knock themselves to pieces, and others that run for many years. Blowers have had a good run in favour, but the last word has not been said. The construction of fans and the determination of the most suitable rates of revolution for a given pressure in the wind chest are better understood now than formerly, having passed out of the realm of empiricism since two or three firms have devoted their energies exclusively to this class of mechanism.

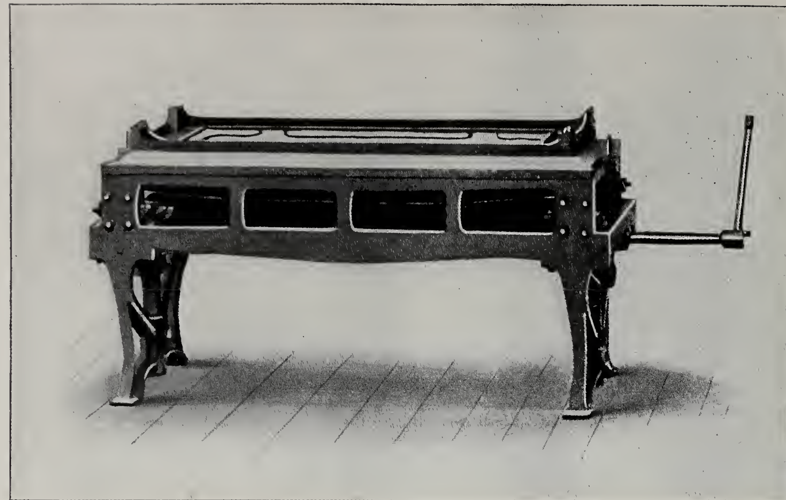
Over and over again the fan and the blower have been discredited through neglect of a little common sense. The fault has not been in these, but in making the connections, or in the rates of revolution. Before considering either, the services of an expert should always be enlisted. One of the most fruitful causes of disappointment has been due to the blast main from fan or blower to the cupola. It has not always been understood that a long pipe of small calibre hinders the proper transmission of the blast. So do sharp bends in pipes. A large pipe or culvert is a necessity if the blower or fan is far from the cupola.

It may not always be practicable, consistently with other arrangements, to have the engine which is used for general foundry purposes close to the cupola. In such a case the self-contained engine and blower are useful. Better still, perhaps, is the motor-driven fan, driven by its own engine, or by a conductor from some other part of the works. Then the fan can be set down close to the cupola and the trouble of long pipes entirely prevented.

A matter that is now in a state of transition in the foundry is the grading of iron. In all foundries a few years ago, and in most to-day, the iron is graded by the foreman, or the melter, by the appearance of fractured faces and by the depletion and breaking of test bars. The chemistry of the laboratory plays no part in this.

If all castings were made from pig of known and regular quality, this would not matter much; but scrap is used, and this of variable quality. Another drawback is that when anything happens to go wrong with iron or coke, experience alone is unable to locate and fix the source of the mischief, and so experiments and trials have to be made with a view to put matters right once more.

Mr. Keep, in the United States, has done more, perhaps, than any other man to assist the practical moulder. By taking advantage of the fact that the shrinkage of metal is a test of the proportion which silicon bears to the mass, he makes this test a means of determining the quality of a given mixture. The fact that silicon throws out carbon from the combined to the graphitic form is also made a means of imparting any given degree of greyness and softness to iron. Certainly, adopting the shrink-



MOULDING MACHINE MADE BY H. E. PRIDMORE, CHICAGO, ILL.

age of a test bar as a measure of the chemical composition of the bar, places a handy practical method in the hands of the furnaceman for judging correctly of the quality of a given mixture before pouring, and affords him the opportunity of modifying it if necessary.

Mr. Keep's tests are valuable from another point of view. The variable degrees of shrinkage in metal of different grades throw great difficulty in the way of obtaining castings of uniform dimensions from the same pattern. An experienced foreman and melter can do much to secure uniformity by the judicious use of special brands and special mixtures. But the best judgment is not wholly reliable, and the modern foundry, therefore, doing a large volume of repetitive and interchangeable work cannot afford to neglect the assistance of the shrinkage tests of Mr. Keep, or the aid of the chemist in grading, or of both in combination. Mr. Keep's method affords the means of grading metal for castings of all dimensions, based on the fact that metal of a given quality has a different coefficient of shrinkage in castings of different sections.

Chemical analyses can never supersede the practical tests by fracture, but they will render valuable supplementary aids which cannot be ignored. The chief value of analysis lies not in the grading of metal from day to day. The melter can do that just as well, when he is once in possession of a stock of well-known brands and uniform scrap. The value of analysis is greatest when error creeps into results, when something abnormal occurs with metal, when a fresh consignment arrives, either of iron or coke, and when a change is made in the relative proportions of mixings, with a view to produce certain results, which, however, do not turn out as desired. Then analysis saves the mixer much preliminary work. An inspection of fractured surfaces is mainly useful in determining the condition in which the carbon is present, but it reveals little or nothing relative to sulphur, which is so injurious an element. An analysis would tell at once whether the percentage of sulphur in a sample were too high, and so provide a sure basis at once for mixing. In a lesser degree, the same applies to phosphorus, manganese, and silicon.

There is one other advantage in the employment of chemical tests. The blame for hard and blown castings is often thrown upon the metal when the real cause lies in the coke,—an error often costly, which cannot be detected and determined except by analysis.

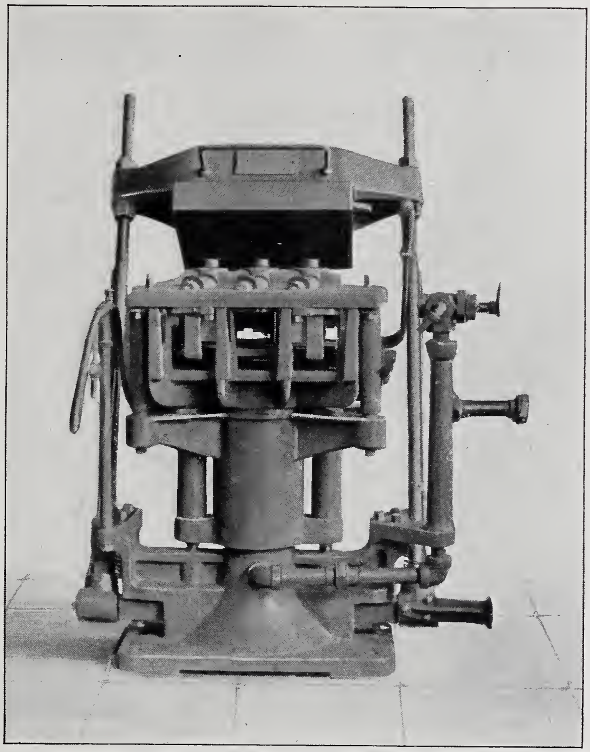
The fettling of castings cannot be done cheaply by the old hand methods: notwithstanding that, many fettling sheds are destitute of any mechanical aids. With the size of castings, and the purposes to which they have to be applied, so will their method of treatment differ. For large, heavy work there is, in most cases, no choice but hand fettling. But with a compressed air installation this need not be the case, except in so far as the removal of runners and risers is concerned, because the pneumatic chipper can be utilised for smoothing over the runner marks, removal of fins and lumps, and the sand blast, with flexible tube, for cleaning off the sand and the rough surfaces.

Castings of medium size can be taken to saws and emery-wheels to be trimmed, and the sand cleaned by blast, the castings being arranged on a table. Castings of small size will be cleaned in the tumblers and the fins ground off against emery-wheels. If they have to be tooled, the acid bath affords the most effectual means for removing the hard scale, the choice lying between sulphuric and hydrofluoric acids. The latter does not affect the iron, but dissolves only the sand.

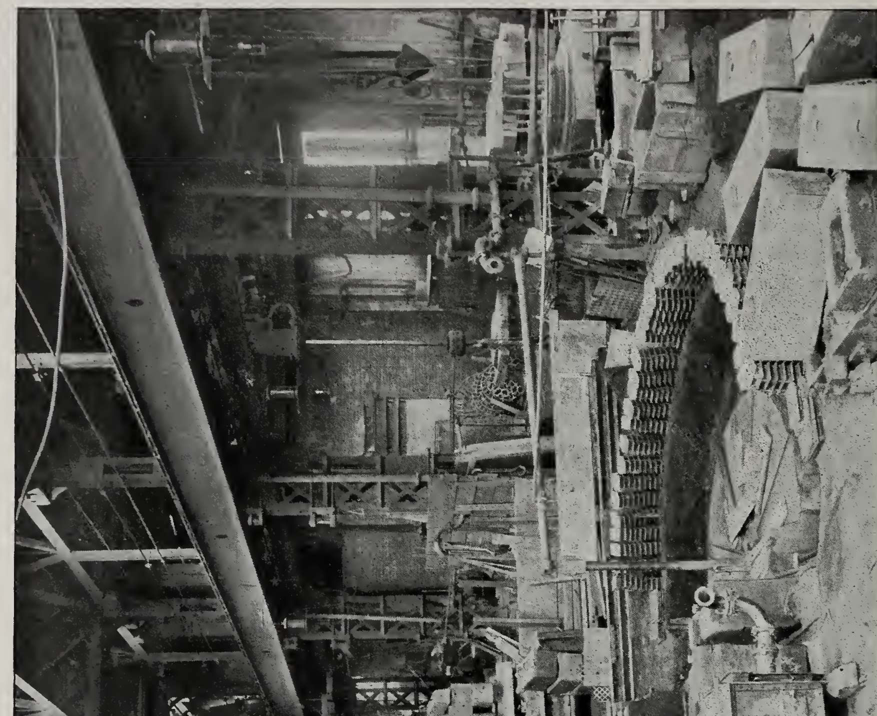
The tumbling barrel will probably retain its place for an indefinite period, being so handy and capable of dealing with a large number of small pieces at one time. But its use is limited, inasmuch as the interior portions of castings and interior angles cannot be scaled in a barrel. Pickling baths are, therefore, necessary adjuncts of a modern foundry dealing with small work which has to be machined.

In the foundry of Sulzer Brothers, at Winterthur, Switzerland, the dust is extracted from the heavy fettling shop by a fan in the end of a chamber built underneath the shop. The chamber runs longitudinally, and measures 9 feet 10 inches deep by 6 feet 6 inches wide at the narrow end, and 10 feet 10 inches wide at the fan end. At right angles with it branches run off, covered with grids, through which the dust is drawn. The sand is afterwards settled by sprinklers.

The fettling arrangements in the light shops of the Sulzer foundry include cleaning by sand blast. A good illustration of these is given in the illustration on page 310. A similar arrangement for removing the dust is employed as that described in the heavy foundry, and one of the floor gratings is shown in the illustration referred to. The two machines shown in the foreground are for cleaning small castings by sand



MOULDING MACHINE MADE BY THE TABOR MFG. CO., ELIZABETH, N. J., U. S. A.



A SULZER FOUNDRY VIEW, SHOWING PORTABLE HOT BLAST FURNACES FOR DRYING MOULDS IN THE FOREGROUND AND A TRAVELLING JIB CRANE ON THE LEFT

blast. The castings are placed on the gridiron table, which revolves, being driven by the horizontal shaft seen at the sides. Above the table, behind the rubber blinds, there is a long, narrow slot, extending radially over one-half the table, and through this the sand and blast strike the castings. The sand conveyor is contained within the square box above, and the dust is carried away through the tubes seen on each side of the machine into the channel beneath the floor. The sand falls on an inclined plane which takes it back to the conveyor.

The applications of compressed air are extending in American foundries, and though a power of youthful growth, it opens out so many possibilities that it is well worth the consideration of all foundry managers. The objection that an air compressor plant has to be laid down should carry no weight in the case of a foundry doing a fair weekly tonnage. The objection to compressed air on account of its elasticity and alleged jerky action is met by the fact that the air compressor automatically regulates the pressure; that is, when the receiver pressure falls below a definite amount, the engine starts working immediately. Then the rest is a question of perfection of connections and of mechanism. As a matter of fact, many foundries are now equipped and working satisfactorily with such plants.

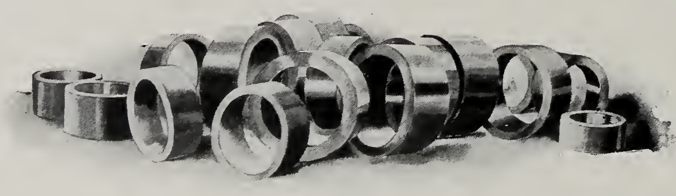
Compressed air applications are manifold, as the preceding pages have shown. The air hoists and cranes distributed about the shop facilitate the handling of the lighter work. Heavy travelling cranes also are operated by air. Chipping castings is performed more rapidly by compressed air tools, though with more noise. The skins of castings are cleaned from scale by the sand blast. Moulding machines are actuated from the same plant. Compressed air has also been used to a slight extent for spraying blackening on dry sand moulds, being used instead of the swab. It also displaces the bellows and dry brush, a flexible tube being employed to blow the sand off pattern faces and the joints of moulds, whether made by machine or on the floor. Foundry flasks have undergone some changes. The wooden ones are disappearing slowly, though in the lumber regions of Canada they still predominate, flasks of iron being rare. In Great Britain it would be difficult to find wooden flasks outside the brass foundries, where many are still used. The development of specialties has had its effect upon flasks, and thus we find that instead of having sides parallel, many, like those used for moulding railway chairs and pipes, have tapered sides, following rudely the pattern contour. One form of flask merits special mention, being used both in brass and iron foundries. It is that in which the inner sides are ribbed so as to hold the sand better. Such flasks serve either as middles, or as cope, or drag, without bars or stays, and their range of utility is thus much increased. Lastly, there is the snap flask which is growing in favour.

The methods of drying moulds in most foundries are about as crude as can be imagined. Of course, there are the drying stoves, heated with coke or with gas. But they do not suffice for more than a portion of the work, a good deal of which must be dried on the floor with a "devil,"—a dirty, wasteful, and not always efficient method, because the heat does not penetrate properly into recessed portions, while others may be over-dried. Much work also is put into the stoves that might be left on the floor if a better method of drying were available.

In the Sulzer foundry a novel method of hot blast drying is adopted. The whole of the shops are served with pipes, starting from 2-foot mains, in connection with which are a number of portable stoves, as shown in the illustration on the page opposite. The cold air, driven by a fan, comes to the stove through 3-inch pipes. Within each stove a fire is lighted. The air supply is controlled by valves, coming in first to burn the coke, after which it is brought over the top of the white-hot fuel into a tube which is connected to the inside of the mould. There are many leakages in the

average foundry, due to want of system in the management of unskilled labour. No moulder should do what an unskilled man can do as well. Neither should the moulders be hampered by the labourers.

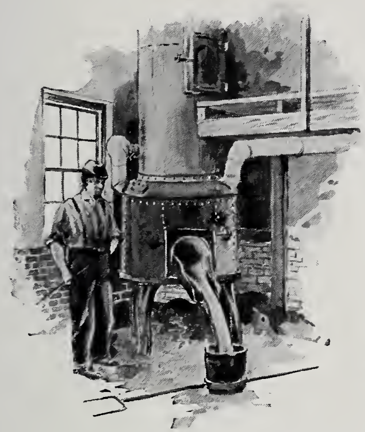
Labour cost in the foundry requires to be taken out very carefully if all work is to be made to pay. The basis taken for estimating should not be the average cost per ton of, say, a year's castings, but the work should be divided out under various sections. If one basis price is taken, then if the classes of work done vary, money will be lost on some orders and prices will be excessive on others. Only in the rare cases in which a foundry does but one class of work can one average be struck. There must, therefore, be several basis prices, and the judgment of the foremen, rather than that of the office staff, should prevail in estimating. Lastly, a word for the men! The moulder's tasks are mostly hard, pursued under wearisome conditions. Often he is expected to produce good moulds with badly-made and wornout patterns, with broken castings, with a few strips and sweeps, to make sound castings with a poor selection of metal, perhaps badly melted; with insufficient tackle, poor light, and few general aids. The trade in its entirety is difficult of acquisition. If you assist a man to become self-respecting he will be a better servant than the hang-dog type of Ishmaelite. The time must come when no foundry will be complete without its private bathrooms, and lockers, numbered for the men. Some employers may smile, but these arrangements already exist in a few progressive foundries.



LABOUR CLAUSES IN PUBLIC CONTRACTS

A BRITISH WARNING, WITH EXAMPLES

By Benjamin Taylor, F. R. G. S.



IT is desirable that the attention of all employers of labour should be directed to the serious menace to industrial freedom which is involved in the so-called "Fair Wage" clauses in contracts with municipal corporations and other local authorities. It is now the acknowledged object of trade unions to endeavour to obtain such a preponderating influence in all town and county councils as to secure the more general adoption and insistence of such clauses. The movement is socialistic in design, and its first aim is to deprive employers of the management of their own businesses. It originated in Great Britain with what is called the "Fair Wages Resolution," which the House of Commons passed in February, 1891, in the following terms:—

"That, in the opinion of this House, it is the duty of the government in all government contracts to make provision against the evils recently disclosed before the Sweating Committee, to insert such conditions as may prevent the abuse arising from subletting, and to make every effort to secure payment of such wages as are generally accepted as current in each trade for competent workmen."

When this resolution had been in force, or at all events on record, for six years, a select committee was appointed to inquire into its working and its effects. This committee interpreted the clause as not meaning that the State should in any way fix or control the rate of wages to be paid, but should merely recognise and uphold "the minimum current rate of wages that might prevail in different trades or districts." They found that the several departments, in giving effect to the resolution, did interpret it to mean that the current rate is "the rate of wages generally accepted as current in each trade for competent workmen in the district where the work is carried out," and that these words were being used in government contracts. And the committee reported their opinion that this is the natural interpretation of the resolution. That it is not the interpretation which the trade unions desire will be seen further on. Meanwhile, in illustration of one of the economic aspects of the resolution, the following is quoted from the report:—

"It was represented to your committee that the effect of allowing a contractor to disregard a rate of wages claimed as current in the district where his yard is situated would be to induce contractors in other parts of the country to do the like, and thus to drive down wages. But it is obvious, on the other hand, that if the Admiralty were to give a higher price for vessels built in one locality, because of higher wages claimed to be current there, a strong inducement would be held out to other localities artificially to raise the wage rate and thus to obtain a like indulgence."

So far, the House of Commons resolution has not been, in itself, the direct cause of any industrial difficulties, though it led the way into the serious position about to be considered. The

government clause is sufficiently elastic to admit of innocuous, and even beneficial, administration by a wisely managed department; and it does not absolutely bind the government in hard and fast lines. What might happen with a government in power by the aid and with the support of the labour vote is not very difficult to foresee. Current wages would be shortly and swiftly converted into trade union wages. The danger attending this resolution, then, is not in its actual effect hitherto in government contracts, but in its existence as a Parliamentary precedent for future possible misuse. Following the example of Parliament, various public bodies throughout the United Kingdom have adopted more sweeping resolutions, the enormities of which we have now to show.

Why are trade unions and trades councils making such persistent efforts everywhere to get their nominees elected to town and county councils and to other representative bodies? It is undoubtedly for the main purpose of getting all these public bodies to adopt what are known as trade union conditions in all public contracts. This is to impose on employers conditions inconsistent with the maintenance of freedom in the management of their works, the right which many of them have successfully vindicated at enormous cost in recent trade disputes, notably that in the engineering trade.

A Parliamentary paper recently gave some information as to the extent to which labour clauses had been adopted by public bodies in urban districts in England and Wales. London and other county councils were not included in the returns, which applied to a population of about 17,000,000. The urban districts of England and Wales were classified as county boroughs, non-county boroughs, and other urban districts. In 115 of these cases the local authorities require current wages to be paid by their contractors. In thirty-four cases the local authorities (ten county boroughs, seven non-county boroughs, and seventeen other urban districts) require wages to be paid at "rates recognised by trade unions." In ten cases the local authorities require wages to be paid at "rates agreed on by associations of employers and employed." In one case only (Hull) the local authority requires the rates to be fixed in the contracts for scavenging, and for other contracts requires the "current rate of wages" to be paid. In four other cases the rates of wages are fixed by the contracts. And in two other cases provision is made that day wages only shall be paid. Thus 163 urban districts make stipulations in their contracts as to wages. These districts have a population of 8,600,000, but if London (which adopts these stipulations) be added, then the local authorities of a population of about 13,000,000 may be said to impose wage conditions. Since the issue of the Parliamentary paper, however, a good many more corporations have adopted such conditions.

These conditions are not always the same under each of the classes. Thus, some local authorities require the wages paid to be those current or recognised in their own district; others that the rates be those of the district in which the work is executed. And in some cases, whilst the stipulation applies only to the contract itself, in other cases it applies generally to all the workmen of the contractor.

Local authorities make conditions other than with regard to wages. Thus, in England and Wales forty-three urban bodies require that the "generally recognised hours of labour of the district or trade be observed." In nine cases the authorities require that the "trade union conditions of labour" be enforced. And in six cases the authorities require their contractors to abide by the hours of labour agreed on by associations of employers and employed. A variety of other conditions are imposed by local authorities. In about thirty cases there are prohibitions against sub-contracting. In no less than thirty-six cases the local authorities reserve the power to dismiss workmen. Several boroughs have standing resolutions giving preference to local trades-

men and local workmen. Some authorities stipulate for the keeping of wage and time books open to their inspectors. One urban district has on record a resolution that "contractors shall perform the whole of the work done by proper workmen at trade union rates of wages." And a typical resolution adopted in other cases is "that no contract or contracts be given out to any firms who do not pay the trade union rate of wages to the work-people in their employ."

Another Parliamentary paper gives similar information with regard to Scotland. In fourteen cases there the local authorities require "current wages" to be paid. Two boroughs specify for "rates recognised by trade unions," but one of the boroughs does not enforce the condition. One specifies that the rates be fixed in contract, but for stone-breaking only; four make conditions against sub-contracting. Three local authorities reserve the power to dismiss the workmen of contractors. Three require that preference be given to local labour. Dundee requires that a contractor shall pay current rates of wages and observe the terms of any agreement that may have been arranged between employer or employed. Glasgow requires contractors to keep a record open to inspection of wages and hours. Partick requires "recognised hours and conditions of labour in each respective trade." The Scotch returns include county as well as borough authorities. They show that seventeen local authorities in Scotland, representing a population of 1,500,000, impose conditions as to wages, etc., and that 235 authorities, representing a population of 2,450,000, make no such conditions. Both returns, however, are upwards of a year and a half old, and since they were issued these conditions have become more general.

It may be of interest to name the county boroughs which require recognition of trade union wages. They are Cardiff, Derby, Ipswich, Newport (Mon.), Northampton, Oxford, Portsmouth, Sheffield, Swansea, and West Ham. The trade union conditions as to hours of labour are enforced by Derby, Ipswich, and Portsmouth. The power to dismiss workmen is reserved by the county boroughs of Dudley and Huddersfield, by three non-county boroughs, and by thirty-one other urban districts. That is to say, these are the official returns, which are not exhaustive.

A new phase has recently been introduced at Manchester, where the corporation in general conditions for electric lighting plant laid down that "the contractor shall execute the works by his own workmen, working directly under the contractor, at a daily or hourly rate of wages, and (except with the consent of the corporation) not by the piece or according to results;" and that the rates to be paid to all workers shall be "the regular standard of wages obtaining in the city of Manchester." By this it will be seen that the weight of municipal influence is to be directed by the trade unions against piece-work. As far as the engineering industry is concerned, the right to piece-work was definitely recognised in the "conditions of management" agreed to and signed by the allied trade unions in January, 1898.

The London county council and some other bodies have sought to reserve the power to dismiss the contractor's foremen; to restrict the number of apprentices to be employed; to attach a schedule of wages and hours to the contract; to insist upon such a schedule being posted in the contractor's works and on the site of the contract.

The Poplar Board of Works, besides requiring that trade union rate of wages (not minimum, current, or standard) be paid on contracts, also stipulates "that the contractors be requested to exhibit at the most convenient place a schedule notifying rates of wages and working hours as specified in the contract and according to the trade societies' rules." They also intimate that compliance with these conditions will be rigidly enforced, with a penalty for every breach of them. A case in point will be presently considered.

Several other corporations, in their contract clauses, call for the posting of a schedule of rates. This is a most ob-

jectionable condition, and one to be strenuously resisted. To post a schedule of rates and conditions on a contract job is tantamount to a public admission by the employer that there is some superior power in the background, to which he is compelled to submit, which comes between him and his work-people. Such an admission is irreconcilable with the independence of employers, and can only provoke trouble with the employees.

In illustration of the tactics which are being adopted, a letter is reproduced below, addressed, under date of May 8, 1899, by the secretary of the Parliamentary and Municipal Affairs Committee of the Amalgamated Society of Engineers to the town clerk of Poplar, apropos of contracts then being negotiated:—

May 8, 1899.

Re Tenders for Electric Plant

I am directed by my committee to notify your board that the firm of —— and—— and Messrs. —— & Co., Ltd., are not considered fair firms by the workmen's trade unions.

Neither of the firms in question pays the wages fixed as a minimum, either at their respective works or in London; neither will they hold intercourse with any one representing the interests of the men; and if time is allowed us we could show by deputation good reasons against these firms having contracts with your board. If we may offer a suggestion, we would say that your board could not do better than give this important work to the well-known firm of Messrs. —— & ——, the next tender being £250 higher.

* * * * * *

We consider this firm, who are trying to raise the status of the workmen, should be encouraged by public boards, such as the Poplar District Board of Works, who, we are sure, will see that unfair contracting firms should not be allowed to secure this work.

These remarks are written without prejudice to any particular firm of contractors. (!)

Awaiting the favour of your esteemed reply, I beg to remain,

Yours obediently,
(Signed) FREDERICK SHIRLEY,
Secretary.

The firms objected to in this letter are of the very highest standing in their industry and are on excellent terms with their employees. The firm recommended in the letter has won a certain amount of notoriety in connection with the eight-hours movement.

Another instance of a deliberate design to boycott a firm has been afforded by the Boilermakers' Society, who, assisted by Mr. John Burns, M. P., Mr. George Dew, and others, effectually prevented the placing of a London county council contract with a certain firm because that firm's shop is a non-union shop, employs piece-workers (at higher wages than those recognised by the trade union), and declined to be controlled by the local branch of the Boilermakers' Society. This firm are now followed, wherever they are tendering to public bodies, by the Boilermakers' Society, who use all their influence to prevent them from getting the contract.

In June, 1898, the London county council placed an order with Messrs. Yarrow & Co., Ltd., for a steam fire float of a special nature, and sought to embody in the contract the conditions above indicated. The general effect of the conditions was to provide an arbitrary standard rate of wages for the various classes of workmen, irrespective of their individual merits. Messrs. Yarrow & Co. declined to accept the contract on such terms, and it was placed elsewhere, at, the writer believes, a much higher price. That the unreasonable character of the demands of the London county council may be fully understood, the writer gives the gist of the clauses rejected by Messrs. Yarrow. They stipulated,—(1) that the county council's officials should have power to dismiss the contractor's foreman, or any other person employed by the contractors; (2) that only apprentices bound to the contractor by legal indenture would be recognised as apprentices;

(3) that the contractors should pay their workmen rates of wages, and should observe or cause to be observed hours of labour, all conforming to a schedule attached to the contract; and (4) that the contractors should keep posted in their own workshop, and also upon the site of the work under the contract, copies of this schedule of rates of hours.

In a contract for boiler work required by the London county council, Messrs. Danks & Co. were the lowest and successful tenderers. The labour members interposed the standing orders, which required such conditions as those above. Messrs. Danks declined the contract on these terms, and it went elsewhere at a higher price. This is a point for political economists and tax-payers to note. In all cases where a higher price is paid to contractors who will accept the labour clauses, the public money is being employed to support the trade union effort to promote socialism. The labour opposition in the London county council to Messrs. Danks & Co. was in the face of the facts,—

(1.) That their shop is non-union.

(2.) That in many instances the men can earn by piece-work higher wages than those recognised by the trade union.

(3.) That they do not pay the rates claimed by the Boilermakers' Society in the South Staffordshire district, and their works are not in that district.

(4.) That they pay as high, or higher, rates than other firms in their own district.

(5.) That other local authorities to whom the Boilermakers' Society has made regular representations had found, on inquiry, that the firm were not infringing their fair wages clauses.

Nevertheless, the Boilermakers' Society persisted that Oldbury is, in their judgment, in South Staffordshire district; that, being in Oldbury, Messrs. Danks ought to pay South Staffordshire rates; and that as they do not do so, they do not comply with the London county council conditions. And the London county council accepted this plea, and recorded their opinion that, although many men were paid higher rates by piece-work than trade union rates, this did not comply with the standing order, that all workmen are to be paid rates "recognised by the trade unions." This deliverance simply means that in all London county council contracts the higher rates of wages justly due to skilled and capable men are to be paid to all the men employed, however unskilled or incapable. It means that men must not be trained to do, at a suitable remuneration, such work as may be too simple or rough for a skilled man; and that men may not be trained to attend to simple automatic machines engaged on repetition work.

In May last the Poplar Board of Works advertised for tenders for electrical equipment. An eminent local firm were the successful offerers. When the contract was presented, a former clause providing for the "minimum standard rate of wages" was struck out by the board, and "trade union rate of wages" was substituted. The tenderers declined this condition, though explaining that they pay the best rates in their district. The board insisted on the clause and on the posting of a schedule. The contract was refused on such terms, and it was given to a firm having the approval of the trade union officials. The following are the terms of the labour clauses rejected by the original tenderers:—

"Rate of wages:—The contractor shall pay to every mechanic, artisan, craftsman and labourer employed in the performance of this contract wages at a rate of not less than the trades union rate of wages in force in the district in which the work is done in their several trades at the date of this tender; and in case of any breach of this condition, the contractor shall pay to the board, by way of liquidated damages, the sum of 5s. per man affected for each day or part of a day during which the breach of these conditions is in force, and such sum may be deducted by the board from any moneys which may become payable to the contractor under this contract, or may be recovered by them in action."

Besides altering the wording of the

contract from "minimum standard rate of wages" to "trade union rate of wages," the board also passed the following resolution:—

"That the contractors who may be ultimately selected be requested to exhibit at the most convenient place on the site of the buildings a schedule notifying rates of wages and working hours as specified in the contract, and according to the engineers' societies' rules."

It is needless to say that this demand for complete surrender of the contractors to the trade unions was at the instigation of the labour members of the board.

The foregoing are cases (and there are many others in Great Britain) in which firms have refused business rather than accept unjust and dishonouring conditions. The following are some cases in which resistance has resulted in the surrender of the public bodies, and the deletion of the clauses.

A little over a year ago the council of West Ham called for tenders for electrical machinery. The offer of a well-known firm of highest standing was accepted, with the intimation that the conditions would be as in previous contracts, plus a new clause relating to wages. When the contract came to be drafted, the council inserted a clause so worded as to require the firm to pay wages according to the standard of a district in which the rates are higher than in the district in which the works are situated. After having reasoned in vain, the firm declined absolutely to accept the unreasonable terms attempted to be forced on them by a town council in which the labourists are in a majority, and which is, perhaps, the most socialistic public body in Great Britain. They withdrew their tender. The town council then advertised for fresh tenders, with even more stringent and objectionable conditions. Several firms tendered, but every one of them, in tendering, struck out the objectionable clauses. Finally the order was placed with the first tenderers without any labour clause at all. By this unsuccessful attempt of the labourists West Ham lost about five months of valuable time, and employers were afforded an example of what can be done by united action in such cases. The following are the terms in the advertisement which all the tenderers struck out in sending in their offers:—

"The contractor whose tender is accepted, and with whom a contract is entered into, will be required to pay all workmen employed by him in or about the contract such rates of pay and observe such hours of labour as are embodied in the schedule, which will be part of the contract. In the event of any breach of such agreement the council will enforce the penalty clause in its entirety.

"A tender will not be accepted unless it is stated by the contractor in the tender, and proved to the satisfaction of the council, that the contractor at the date of the tender pays to the whole of his workmen such rates of wages and observes such hours of labour as are recognised by the workmen's trade unions in the several localities where his work is done. If, after the contract is signed, it shall be proved that the said statements of the contractor in the tender are contrary to fact, the council shall be entitled to rescind the contract, or at its option to recover from the contractor as liquidated damages, and not as a penalty, the sum of £50."

And the following are the contract clauses which all the tenderers concurred in rejecting, and which the council were compelled to delete:—

"The contractors shall at all times during the continuance of this contract abide by, perform, observe, fulfil and keep all and singular the stipulations following, that is to say:—

"1. The contractor shall pay all workmen (except a reasonable number of legally bound apprentices) employed by him in and about the execution of this contract, or any part thereof, wages, and wages for overtime, respectively, at rates not less than the rates stated or provided for in the schedule hereto attached, and for each and every breach by the contractor of this stipulation, and notwithstanding the condonation of any prior or other breach, the contractor shall, on demand, pay to the council as

liquidated damages, and not as a penalty, the sum of £5.

"2. The contractor shall observe, and cause to be observed, by such workmen, hours of labour not greater than the hours of labour stated or provided for in the said schedule, and for each and every breach by the contractor of this stipulation, and notwithstanding the condonation of any prior or other breach, the contractor shall, on demand, pay to the council as liquidated damages, and not as a penalty, for each day or week, as the case may be, in which any such breach shall be committed, and for each workman in respect to whom it shall be committed, the sum of 5s. per hour for every hour during which in each day, or week, as the case may be, each workman shall be employed by the contractor beyond the maximum number of hours stated or provided for in the said schedule, provided that this stipulation shall not be construed to prohibit overtime, if such overtime be in accordance with the rules of the trade unions concerned.

"3. The contractor shall at all times during the continuance of this contract display, and keep displayed, upon the site of the works, and in every factory, workshop, or place occupied or used by the contractor in or about the execution of this contract, in a position in which the same may be easily read by all workmen employed by the contractor in or about the execution of this contract, a clearly printed or written copy of the said schedule hereto, and for each and every breach by the contractor of this stipulation, and notwithstanding the condonation of any prior or other breach, the contractor shall, on demand, pay to the council as liquidated damages, and not as a penalty, for every day during which such breach shall be or continue, the sum of £3."

The West Ham case is peculiarly interesting and instructive because the West Ham council prides itself on being the most democratic municipal body in Great Britain. At the elections of 1898 the trade unions agreed to sink their differences and to put forward ten labour candidates for the council. There are, the writer believes, 28 labourists members and sympathisers in a council of 44. The fact that by presentation of a united front on principles essential to the freedom of industry, labourist tactics can be defeated in a constituency such as this, is of the highest significance. The contract, with the labour clauses altogether expunged, was confirmed by 26 votes to 17 when it was found that no responsible firm in the trade would accept the order on such conditions as the labourists wished to impose. And just about the same time the council of West Ham had to agree to expunge these clauses from a contract for a steam-roller, which they could not get any maker to supply on their terms. It was in West Ham that one of the labour members (himself a trade union official) caused all the non-unionist bricklayers employed by the corporation to be discharged.

In March last the Islington vestry wished to give out a contract with the conditions that the contractors should promise to pay the trade union rate of wages, and cause a schedule of this to be exhibited in their works. Not one of the firms offering would agree to these conditions, and as the vestry could not prevail on any respectable firm to accept them, they had to strike out the clauses of their building contract.

A similar case occurred recently at Tottenham, where the urban district council wished to attach a similar clause and schedule to a contract. All the tenderers struck out the clause when offering, and the council had to waive it.

The corporation of Leeds not long ago ordered the insertion in their gas-coal contracts of a "Fair Wage" clause, accompanied by a heavy penalty clause. The Associated Coalowners, after full consideration of the matter, agreed to refuse to accept the new form of contract. In consequence, the corporation have had to strike out the objectionable clauses. There was another case at Leeds recently in which the corporation desired to embody in a contract for some engineering plant certain clauses as to rates of wages, hours of labour, the keeping of a record of these, always open to the inspection of the

officials of the corporation, and so forth. The firm whose tender had been accepted simply struck out all these clauses and refused to sign a contract containing them. The corporation eventually confirmed the contract without the objectionable clauses. Leeds is one of the county boroughs which, according to the Parliamentary paper previously quoted, has adopted the "current rates" clause for public contracts.

In June last the corporation of Sheffield accepted the tender of Messrs. S. Z. de Ferranti, Ltd., for some electrical machinery. In the contract it was proposed to insert a clause adopted some time ago by the town council requiring, *inter alia*, that "all workmen employed in carrying out a contract in the city of Sheffield shall be paid not less than the standard rate of wages recognised by trade societies in Sheffield in each branch of trade." Messrs. Ferranti pointed out that such a condition is contrary to the agreement entered into between the Engineering Employers' Federation and the allied trade unions for the regulation of wages, etc. The trade unionists got pressure to bear in and out of the council to have the clause insisted on. Messrs. Ferranti stood firm, however, and would accept the contract only with a clause to the effect that the workmen engaged under it should be "paid a rate of wages and observe the hours and conditions of labour as recognised between the Masters' Federation and the representatives of the men's trade unions for the Oldham district." After a stormy scene in the town council the contract was confirmed on Messrs. Ferranti's terms, but only by 26 votes to 23. The narrowness of the majority affords a fair indication of the strength of the forces with which employers have to contend.

The following is the text of the Sheffield resolution, which was set aside in the case of the Ferranti contract:—

"City of Sheffield. At a meeting of the council held on Wednesday, the 25th day of October, 1893, it was resolved:—that the resolution on contracts proposed by Alderman Jackson, and adopted by the council on the 28th day of June last, be rescinded, and the following be substituted and inserted in all invitations for tenders for work under the corporation, viz.:—'The contractor will be required by the contract to agree that all workmen employed in carrying out the contract in the city of Sheffield shall be paid not less than the standard rate of wages recognised by trade societies in Sheffield in each branch of trade represented in executing the contract, and to observe the recognised hours and proper conditions of labour. And for all work prepared outside the city of Sheffield and to be used in the city the minimum standard rate of wages paid by (?) trade societies where such work is prepared; and if there be no such standard of wages in such place, then the contractor will be required to adopt and pay the Sheffield rate of wages, and abide by the other conditions as if such work had been executed in Sheffield. The contract will prescribe, as the liquidated damages to be paid by the contractor in case of breach of the condition as to wages, a sum of money equal to three times the amount by which the actual rate of wages paid by him at any period during the execution of the contract for any particular class of work is below the minimum standard rate of wages ruling in Sheffield and district for the same class of work during that period. These conditions shall also apply to sub-contractors.'"

Sheffield is among the list given in the Parliamentary paper of county boroughs which have adopted for contracts the rates of wages "recognised by the trade unions," but the new resolution out-Herods Herod. It will be observed that it gives no voice to anybody but the trade societies. Those who pay the wages are completely ignored, as to any right they may have either in fixing the wages to be paid, or in ascertaining what may be the wages current in the district. Mutual agreements are completely set aside. It is the trade societies of Sheffield alone that shall decide what wages shall be paid for men working under any contract for the city,—no matter what an employer

may contract for with his men to do the work. The council requires recognition by contractors of an economic absurdity, a standard rate of wages applicable to all the men of a class in any district. The writer would particularly direct attention to the terms of the Sheffield clause, because though it was, by special resolution of the town council, set aside in the case of the particular contract to which reference has been made, it still remains in what one may call the statute book of the corporation. And at meetings of trade unions and the labour party, and in the public prints, it has been openly declared that the labourists are determined that the resolution shall remain on the minute book and shall be put into force in future contracts. The design is to get such a preponderating vote in the town council as to be able to prevent such a return to reason as was effected in the Ferranti case. We see, then, the forces at work towards making the trade unions masters of the situation by giving them not merely the determining, but also the sole, voice in all public contracts. The successes which some employers have made in resisting these unjust conditions have only stimulated the energies of the trade unionists and labourists. For instance, the Amalgamated Society of Engineers have recently sent round among their districts an urgent reminder that "it is incumbent on all trade unionists who are interested in the maintenance of trade union conditions in the making of public contracts, that they should bestir themselves and make their influence felt in their respective municipal districts, as well as in Parliament, through their representatives."

Now these labour clauses are not only unfair in themselves,—they are also opposed to the true interests of labour. It is an essential condition of successful industry that every workman shall be rewarded according to his ability. The labour clauses would compel all workers, however lazy and incompetent, to be paid the same rate of wages as the skilled and industrious workman. They would establish not fair wages, but an arbitrary uniform minimum rate fixed by the trade unions alone,—not by those who have to pay the wages. And the ultimate result will be to deprive all employers of the management of their own trades.

As far as the engineering trades are concerned, the issues are clear. The employers in these industries had a prolonged struggle to maintain their own freedom in the management of their own works. Their efforts in this direction culminated in the great British engineering trades strike of 1897, which ended in a treaty of peace in January, 1898. To obtain this settlement the employers made enormous sacrifices, and by that treaty the trade unions entered into formal obligations with regard to their future working. The unions are now going behind this agreement, and are endeavouring to place public bodies between them and their obligations. This may be shortly shown. The following is clause 4 of the "Conditions of management mutually adjusted and agreed upon between the Federated Engineering Employers and the Allied Trade Unions," in January, 1898, and signed by the representatives of the employers and of the Amalgamated Society of Engineers and allied unions:—

"Employers shall be free to employ workmen at rates of wages mutually satisfactory. They do not object to the unions or any other body of workmen in their collective capacity arranging amongst themselves rates of wages at which they will accept work; but, while admitting this position, they (the employers) decline to enforce a rule of any society, or an agreement between any society and its members. The unions will not interfere in any way with the wages of workmen outside their own unions. General alterations in the rate of wages in any district will be negotiated between the employers' local associations and the local representatives of the trade unions or other bodies of workmen concerned.

"Note.—Collective bargaining between unions and the employers' associations is here made the subject of distinct agreement."

The essence of this clause in the

agreement is that the wages are to be the subject of mutual arrangement, not of arbitrary decree on one side or the other.

The sixth clause of the agreement has reference to the selection, training and employment of operatives, and has a distinct bearing on what we have seen of some of the actions of trade unions with regard to public contracts. It runs as follows:—

"Employers are responsible for the work turned out by their machine tools, and shall have full discretion to appoint the men they consider suitable to work them, and determine the conditions under which such machine tools shall be worked. The employers consider it their duty to encourage ability wherever they find it, and shall have the right to select, train, and employ those whom they consider best adapted to the various operations carried on in their workshops, and will pay them according to their ability as workmen.

"Note.—There is no desire on the part of the federation to create a specially favoured class of workmen."

Special attention is invited to this clause, formally accepted by all allied trade unions, because it is utterly and entirely opposed to the claim now being made by, or on behalf of, the trade unions, that no men shall be employed on public contracts at less than trade union rates of wages. There is no standard rate of wages in the engineering trade. There is a standard of merit by which to regulate wages.

The concluding condition of the agreement contains provisions for avoiding future disputes, the general principle of which is shown in the first clause:—

"With a view to avoid disputes in future, deputations of workmen will be received by their employers, by appointment, for mutual discussion of questions in the settlement of which both parties are directly concerned. In case of disagreement, the local association will negotiate with the local official of the trade union, with power of appeal to the executive board of the federation and the central authority of the trade union, acting in conjunction."

The principle of mutality is thus repeated and confirmed. But it is not the engineering trades alone that are concerned with public contracts. The building trades, for instance, are much more largely concerned, and there are a very large number of trades and industries which have, or desire to have, public bodies as their customers. By common agreement and concerted action among employers in all the trades it will be possible to compel the deletion from all public contracts of clauses giving the purchaser the power to lay down the rates of wages to be paid, or the hours of labour to be observed, or to dismiss foremen or restrict apprentices, and to prohibit working by piece-work or payment by results. By such common agreement it can be upheld as a general principle that fair wages are not what trade union representatives may choose to specify, but the rates agreed upon between employers and employed, either individually or collectively. The trade unions proclaim the principle of collective bargaining, yet their present aim is to eliminate it from all public contracts, and it is to defeat this aim that employers in all trades ought to combine, if they value their own liberty.

THE STEEL ARCH OVER THE NIAGARA RIVER AT NIAGARA FALLS

MACHINERY IN BRIDGE ERECTION

By Charles Evan Fowler, M. Am. Soc. C. E.

WHAT is given in the following pages is intended to show, in some measure, the extent to which machinery has become identified with bridge erecting operations. In these, as in work of nearly every other kind, labour-saving devices have become practically indispensable, and it is to their appreciation and constantly widening introduction that the American bridge shop at the present day owes much of its reputation for low-priced, good work, and rapid work as well. Mr. Fowler's present article is the legitimate conclusion to what he presented in the January number of this magazine under the title of "Some American Bridge Shop Methods."—THE EDITOR.

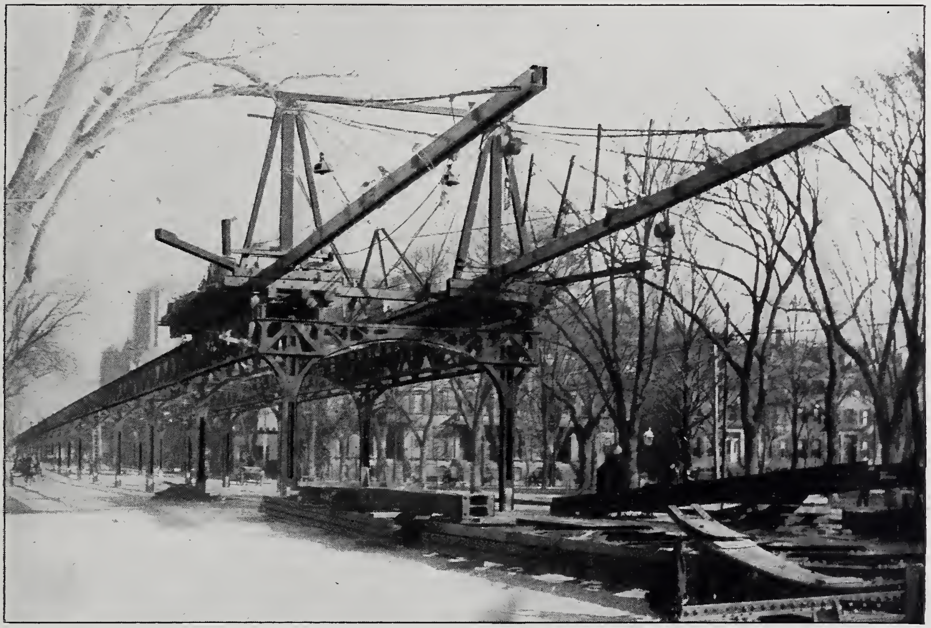
American pin-connected bridges are all built to conform to a general type, but while the several spans of any one bridge may be exact duplicates, it is seldom that a second contract is made in which the same plans can be used again. Should the span length be identical, the loading would most likely be different, so that the sections of the members would not be the same. Not only is it impossible to carry bridges in stock, but it is very nearly impracticable to keep in stock the material which would be required to build one of any considerable size.

The practice which was followed in some shops years ago of laying out the rivet spacing and other dimensions di-

IN THE ERECTING TOOL HOUSE OF THE BERLIN IRON BRIDGE COMPANY AT EAST BERLIN, CONN.

rectly upon the iron plates and shapes made it impossible to have like members exact duplicates, and it was necessary to fit together the various parts forming a truss in the yards before shipment and to give to each one a distinctive mark, so that they would occupy the same positions when the structure was erected.

The almost universal employment at the present time of the templet system makes it possible to have all the members with like dimensions practically duplicates, owing to the fact that all like pieces are laid off from the same wooden pattern. With the members of the same size interchangeable, shipments can be made to the bridge site as fast as cars can be filled. A careful manager will have the shop begin work upon the portions which are needed first and continue the manufacture in an orderly manner, so that as soon as material begins to arrive at the bridge the erectors can commence work and continue it without interruption until the structure is complete.



A TRAVELER USED ON THE BOSTON ELEVATED RAILWAY BY THE TERRY & TENCH CONSTRUCTION COMPANY OF NEW YORK

The storehouse for erection tools is a very important feature of a first-class bridge-building plant, and its completeness and arrangement furnish a good index to the methods of erection pursued by the company. Places are provided for hanging the ropes and blocks, for keeping the bars, sledges, hammers, jacks, forges, together with hundreds of other tools and erection devices, and, lastly, room where the hoisting or erecting engines may be stored. When tools are returned from a completed bridge, they should be repaired at once for prompt shipment to another point in case of emergency. The engines usually require overhauling and repacking each time they are returned.

Pin-connected bridges are erected by the use of false-work or staging, modeled after the American railway trestle, with plumb posts, batters, caps, sills, and bracing of timber, all bolted together to properly carry the weight of the bridge and traveller, to resist the force of the elements, and oftentimes the loads, vibration, and traction stresses

A TYPICAL BRITISH COLONIAL BRIDGE

ERECTING PLATE GIRDERS

when trains must be kept running across. One of the most extensive pieces of false-work ever erected is the one now in use by the Terry & Tench Construction Company in the erection of the approach spans of the New East River bridge, in New York City, the height being 120 feet above the water and the width on top about 66 feet. Piles were driven in the bed of the river as a foundation on which to carry the enormous weight of the false-work, traveller and steel work of the bridge. On top of the false-work, on rails, runs the traveller of typical American construction. This is, in effect, a travelling derrick or gantry crane of timber, mounting derricks, carrying arms for attaching falls used in hoisting, and provided with platforms below, on which are set the hoisting engines.

The erection of a pin-connected bridge is accomplished by assembling it piece by piece, as is shown in the illustration on page 333, driving pin after pin, as the panels are completed, partially bolting up the connections where rivets are to be driven, or actually riveting portions of the floor system, so that when the last pin of a span is driven the camber blocks or wedges which support the span on the false-work may be knocked out and the span swung clear. Riveted trusses in Great Britain and on the European continent, on the other hand, are most frequently either riveted up at the shops or on the bank of the stream and launched out complete into place, as shown in the illustration on page 332 of the erection of a railway bridge over the river Trent.

A similar method has been employed in America in erecting pin-connected spans, by the erection of the trusses on false work supported on pontoons near the bank. When the span is complete, the pontoons are floated to the location of the span, and the truss is lowered into place by scuttling the pontoons.

Heavy American plate-girder spans are often riveted together complete at the shops and placed in position in this condition. The girders illustrated on page 330 are 91 feet in length and weigh over 40 tons per span. They were to replace old wooden Howe truss deck spans. Loaded on three platform cars, a span would be switched out on the old structure, hoisted up by the gallows

TYPICAL AMERICAN BRIDGE ERECTION

frames, the cars pushed away from underneath, the deck and bracing of the old span torn away and the girders lowered into their final position between the timber trusses, which were afterward torn away. The time occupied in the erection of one span was about six hours.

The bridges which have been built by British and continental shops for export to foreign countries and to their colonies are mostly of riveted construction, similar to the Australian span illustrated on page 330. Short spans of riveted construction are undoubtedly stiffer under

A BRITISH METHOD OF LAUNCHING RIVETED GIRDERS

traffic than pin-connected structures, and many American engineers are employing riveted connections either in the lateral or sway bracing, or for the entire structure where the length is under 200 feet. Where riveted main trusses are employed, they are, however, made with simple, single intersection web systems instead of the multiple systems which have been so extensively employed by other engineers.

Riveted work is somewhat cheaper to construct in the shops, but owing to the hundreds or thousands of rivets to be driven in the field, the cost of erection is, or has been, considerably greater. The difference will, doubtless, be entirely overcome by the use of various machines which have been designed for use in erection work, such as power drills and reamers, chipping devices, power riveters, and the like.

The growing scarcity of timber has caused the travellers on some work to be made of steel, as was the case with the Niagara arch, where two steel travellers were employed. Overhang travellers, such as are employed for the erection of cantilevers and high viaducts, are usually constructed wholly or in part of steel. They may be made to move easier by using roller-bearing trucks, while the boom or derrick seats are made with either ball or roller bearings to reduce the friction to a minimum. Large wire rope blocks or large blocks for manila rope should always have either roller bearings or anti-friction bushings.

ERECTING A PIN-CONNECTED ARCHED BRIDGE

The simple drum engines of earlier years have given way almost entirely to specially designed bridge erection engines. When most of the hoisting is to be done by wire rope falls, the engine is fitted with one or two friction drums, which are operated independently, and on the ends of the drum shafts are fixed spools for use

AN EXTENSIVE PIECE OF FALSE WORK USED IN ERECTING THE APPROACH SPANS OF THE NEW EAST RIVER BRIDGE, NEW YORK CITY

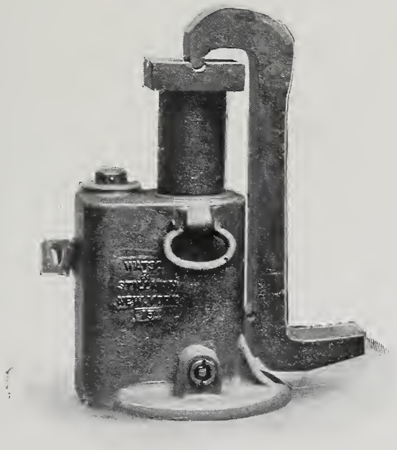
with manila rope. The necessity at times of winding in several hundred feet of large manila rope makes it impossible to use drums for the purpose, while with the spools it can be wound in and coiled back of the engine. Drum engines of this type are often provided with an extra geared shaft in front, on each end of which is a spool, running loose, but thrown into gear by a hand lever on a quadrant. They are provided with ratchets to hold the load after they are thrown out of gear.

When it was necessary to provide power to swing the booms on a traveller, it was customary to provide two extra drums on the front for this purpose; but a recent improvement is the extension of the drum shaft, so that a smaller spool is introduced between the regular spool and each drum for swinging the boom, the operation being independent of the others. The extension of the shaft is provided with an extra bearing between the two spools. This device is in use on the traveller engines on the Boston Elevated Railway for swinging the 60-foot booms shown

in the illustration on page 329 when handling the girders and columns.

The assembling of the members of a large truss span necessitates the handling of several members in each truss at one time, and the large, heavy pieces have a set of falls attached to each end. The bridge erecting engines for this purpose have no drums, but four, six or eight large spools, each one operating independently, being controlled by a hand-lever clutch and a ratchet, so that it is possible to go ahead with either end of a member independently of the other, to hold either end, or the entire piece, while a pin is being driven. Some of the heads are geared to work faster than the others for hoisting the lighter members, and the surface of each spool is finished and polished to cause little wear on the rope.

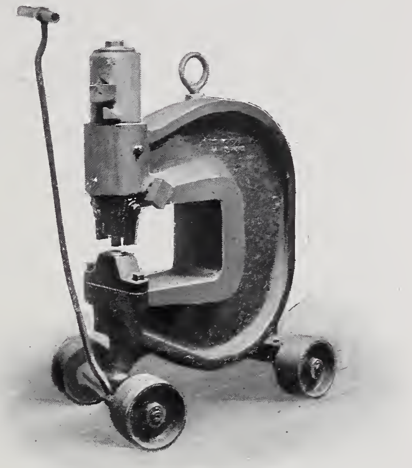
The customary power for all hoisting engines is steam, supplied from a vertical boiler, set upon the same base casting with the engine, but electric motors are beginning to be used wherever the power lines are convenient to the work, with a positive saving in cost in some cases, and an indirect saving in others,



A WATSON-STILLMAN HYDRAULIC JACK FOR BRIDGE WORK

on account of the work being very much facilitated and the moving of the hoist being much easier, due to increased compactness and reduced weight.

With one of the large spool engines for hoisting, a bridge can be erected with almost magical rapidity. One of the bridges of the Pennsylvania Railway across the Susquehanna River, which consists of a large number of 200-foot



A PORTABLE HYDRAULIC PUNCH. MADE BY THE WATSON-STILLMAN CO., NEW YORK

spans, was originally a wooden structure. When it was blown down a few years ago the contract for replacing it was let to two of the large bridge companies, who started the erection from opposite sides of the river and raced across. It was found possible to erect a span in seven hours' actual time. This covered only the erection of the steel, it being delivered by other gangs of men, while still other men erected and removed the false-work.

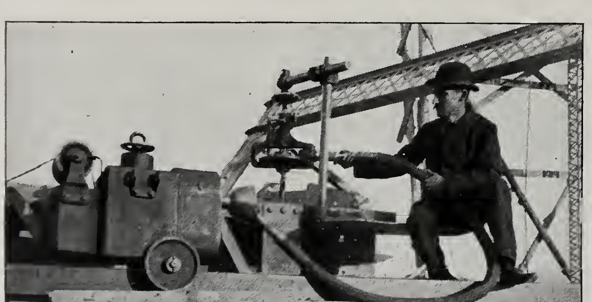
The handling of heavy girders is often effected by using heavy hydraulic jacks, which are commonly known as pump-jacks. Those generally used are of from 20 to 60 tons capacity, and are the most efficient means of raising heavy weights that can be used. The arched form of the bottom chord of a certain cantilever was the cause of one of the anchor spans, weighing over 400 tons, creeping about two inches from its proper location during its erection. As one end of the span rested on 12-inch expansion rollers of the segmental type, it was only necessary to ease up the other end and force the span ahead, which was done by

A COMPRESSED AIR RIVETER. MADE BY THE CHICAGO PNEUMATIC TOOL COMPANY

means of six heavy hydraulic jacks resting on the false-work in a raking position, to raise upwards and push forward at the same time, and the span was moved to place as easily as a push-car could have been shoved ahead by hand.

The moving of smaller structures of light weight is often accomplished by employing lever or screw jacks, which are in such common use as to require no extended comment.

With the exception of the hoisting engines, it has been usual to do all the field work with hand tools, which, in many instances, were slow and expensive to use, and oftentimes the cause of direct injury to the material. Some classes of work have numbers of beams, channels or other pieces in which there are but few holes to be punched, so that they may be shipped plain from the mill directly to the bridge and the holes punched or drilled at the site. When the number of holes is sufficiently large to warrant it, a lever punch may be used and several hundred holes punched each day, but where there are only a few holes to be made a small screw punch can be used. The ordinary form is a single cast yoke, one arm holding the



AN ELECTRICALLY DRIVEN FLEXIBLE SHAFT FOR BRIDGE WORK DRILLING. MADE BY THE STOW MFG. CO., BINGHAMTON, N. Y.

die and the other the punch and screw head, which is operated by a lever bar inserted in the capstan head.

Another form is the duplex screw punch, which has a double screw with right and left threads for operating a toggle, which makes it possible to punch larger holes with a small expenditure of power. The hydraulic screw punch has the ordinary shape of yoke, but the hand screw enters a chamber which is filled with oil or other liquid; the pressure is transmitted to the punch holder, which is of much larger diameter than the end of the screw, through the liquid, and thus the power is multiplied in a manner similar to that followed in other hydraulic tools.

The making of large holes, or of holes through thick metal, requires the use of either a hydraulic punch or of some kind of drill. The hydraulic punch is provided with a large chamber similar to that on a hydraulic jack in which are the pump and valves. The pump is operated by a hand lever on the outside, below which is the valve for releasing the pressure when the hole has been punched. The operation is so slow, however, as to preclude its use for anything except special cases; the number of holes which can be punched in a day will seldom exceed two hundred. Three or four men are required to handle and operate one of the punches, so that the use of ratchet drills, which require only one man each, is often more rapid. The ordinary ratchet has a

A PORTABLE ELECTRIC AIR COMPRESSOR. MADE BY THE CHRISTENSEN ENGINEERING CO., MILWAUKEE, U. S. A.

12-inch handle, while a drilling bracket is clamped on to the member against which the feed screw bears. With an ordinary amount of shifting of the bracket about 20 lineal inches may be drilled in one day. This represents forty holes in half-inch metal, although by crowding the work, double the number may be put in.

Where electric wires run near the work an electric motor can be used to operate some form of drill and the number of holes multiplied several times. The Stow flexible shaft represents one of the best forms of apparatus for this kind of arrangement. The shaft is made up of a number of coils of steel wire, one overlying the other, and covered with a casing. The ends, for a short distance, are brazed solid to receive the couplings.

The motion was originally communicated by a belt, but the later forms have electric motors to drive them or else compressed air motors may be used. The great economy of the device is due to the fact that a large number

ANOTHER Q & C RIVETER

of holes may be reached with the machine placed in one location, although it may be easily moved, as the motor can be mounted upon a small truck. The end of the shaft can be carried to places on a bridge where it would be impossible to go with some of the heavy reaming or drilling machines.

ELEVATED RAILWAY WORK WITH A PNEUMATIC RIVETER MADE BY THE Q & C COMPANY, CHICAGO

The use of compressed air drilling machines, pneumatic riveters, and other machines using compressed air, at the same time that erection work is in progress, makes it necessary to provide another source of power than the hoisting engine boilers. When the work is concentrated, a separate boiler may be provided, but when it is strung out over several miles, like elevated railway construction, the entire plant must be readily portable.

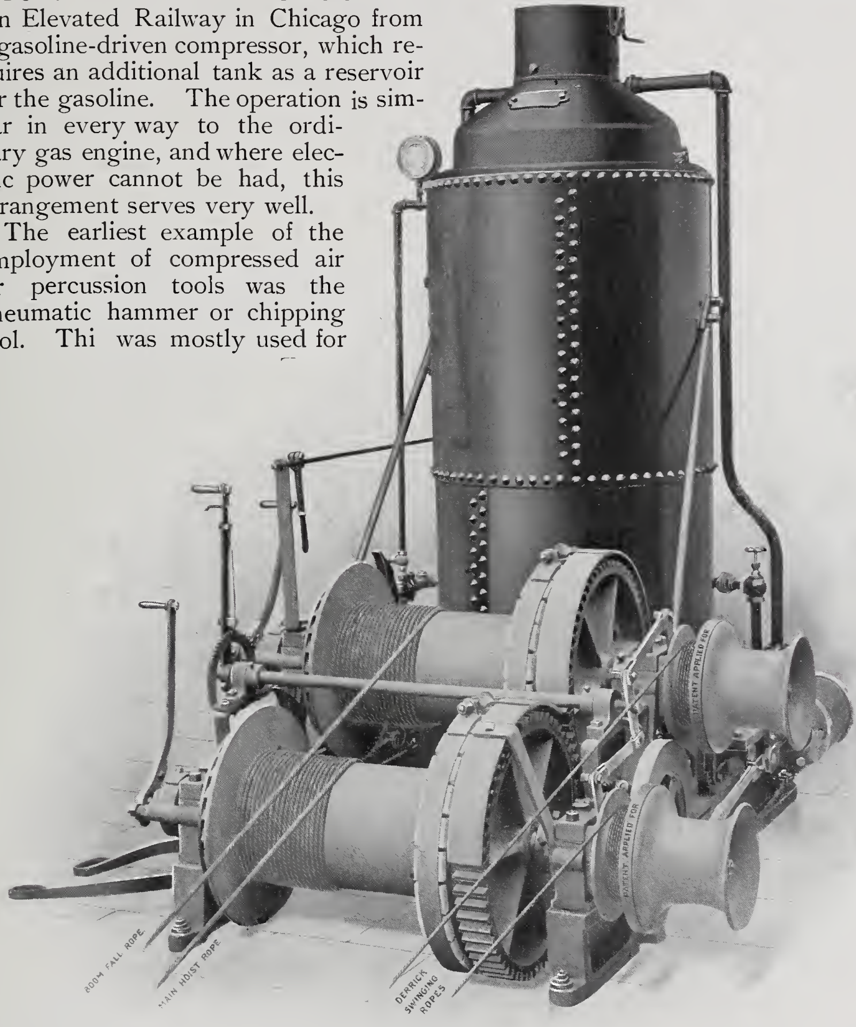
The most desirable from every point of view, when electricity is available, is the electric motor. Motor-driven compressors may be had of various makes; in fact, any make of compressor can be readily driven electrically, although but few firms regularly manufacture compressors of small capacity fitted with electric motor for driving.

A compressor having a capacity of 100 feet is only about 4 feet 9 inches long, 3 feet 6 inches wide, slightly over 3 feet high, and weighs 4600 pounds. The current may be taken from any conveniently located lighting or power circuit. For erection work the compressor is mounted on a truck which

also carries the receivers, and an automatic device is provided to stop the motor when the pressure has reached the required point and to start it again when it has dropped to the minimum.

Power is obtained on the Northwestern Elevated Railway in Chicago from a gasoline-driven compressor, which requires an additional tank as a reservoir for the gasoline. The operation is similar in every way to the ordinary gas engine, and where electric power cannot be had, this arrangement serves very well.

The earliest example of the employment of compressed air for percussion tools was the pneumatic hammer or chipping tool. Thi was mostly used for stone cutting, and consisted of a cylinder enclosing a piston which, upon the admission of the air, was given a percussive movement through the proper arrangement of inlets and cut-offs, and hammered upon the end of the tool inserted in one end of the cylinder. The handle was provided with an opening and valve for the admission of the air. The pneumatic chipping hammer is of similar construction, though much heavier, and is of great service where chipping must be done in the field, provided there is a compressed air plant on the work. While it cannot be worked in every location in among the bracing of a bridge, on plain cuts it will make a saving of from 50 to 75 per cent. over hand work, using about twenty cubic



A TYPICAL AMERICAN BRIDGE ERECTING ENGINE. BUILT BY THE LIDGERWOOD MFG. CO., NEW YORK

ERECTING AN AMERICAN RAILWAY VIADUCT

feet of free air per minute, and making over 2000 strokes per minute.

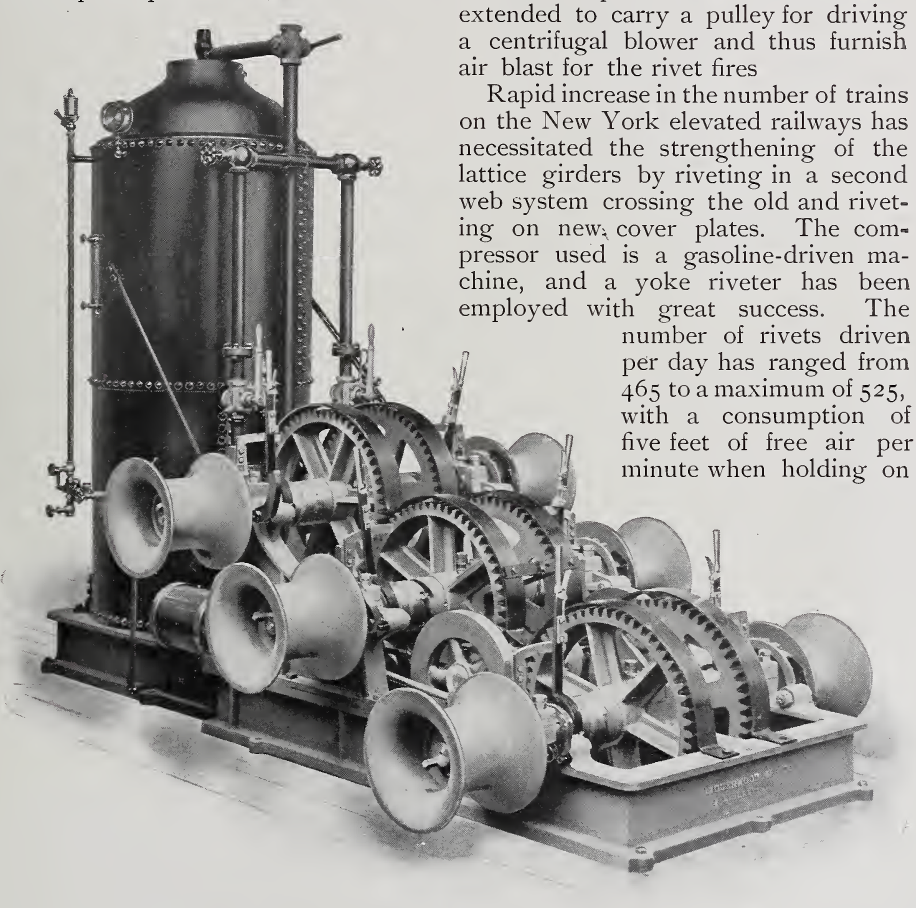
Exactly similar to these hammers are the pneumatic percussion riveters; in fact, the largest sizes of hammer are used for riveting with small rivets by substituting a rivet snap for the tool. One form of riveter for driving rivets from ¾ to 1 inch in diameter weighs about 25 pounds and makes about one thousand 5-inch strokes per minute. The rivets are usually held up by a solid or spring dolly, but a pneumatic dolly is used where there is a parallel surface a short distance from the rivet against which to place it. This form of riveter is being extensively used both on the Boston and the Chicago elevated railways. At Boston, owing to the scattered and cramped positions of the rivets, it has not been possible to drive over about 300 rivets per day, which has been exceeded in many instances by hand gangs. The record at Chicago

shows a maximum number of 500 rivets per day, a much better record than for hand work, but certainly not up to the capacity of the riveters. Percussion riveters set in yokes have been used more extensively at Chicago than at Boston, where the ordinary or gun riveter has the preference on account of the character of the work. The air pressure used in each case is about 100 pounds per square inch, and when it falls below 90 pounds good work cannot be done.

The riveting on a three-track, 70-foot girder span on one railway was done by a percussion riveter set in a lattice yoke with a reach of 40 inches, driving groups of sixteen rivets in ten minutes, and a maximum of 900 rivets in a day of nine hours. Where rivets could not be reached with this machine a gun riveter was used, driving as many as thirty rivets in ten minutes, but not reaching more than 500 rivets in one day of nine hours. Each of these machines required but two men in addition to the heater.

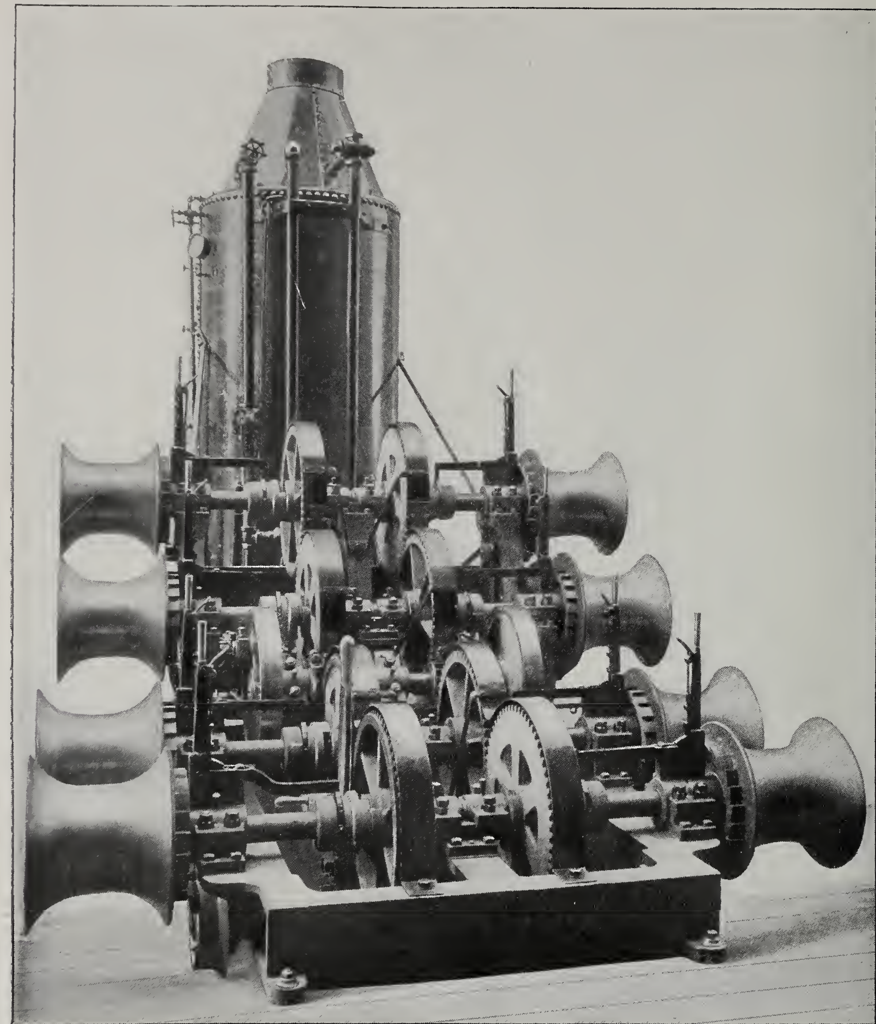
The forges for heating rivets on the Chicago work are blown by compressed air, while the armature shaft on the electric compressor used at Boston is extended to carry a pulley for driving a centrifugal blower and thus furnish air blast for the rivet fires

Rapid increase in the number of trains on the New York elevated railways has necessitated the strengthening of the lattice girders by riveting in a second web system crossing the old and riveting on new cover plates. The compressor used is a gasoline-driven machine, and a yoke riveter has been employed with great success. The number of rivets driven per day has ranged from 465 to a maximum of 525, with a consumption of five feet of free air per minute when holding on from six to eight seconds per rivet.



A LIDGERWOOD SIX-SPOOL BRIDGE ERECTING ENGINE, WITHOUT DRUMS

When the Victoria Bridge across the St. Lawrence River, near Montreal, was built by Robert Stephenson, the tubular type represented the height of perfection. It was, therefore, adopted, and the great iron tunnel of plates and shapes, with its thousands of connecting



AN EIGHT-SPOOL BRIDGE-ERECTING ENGINE, BUILT BY J. S. MUNDY, NEWARK, N. J., U. S. A.

rivets, was built on the massive stone piers. The growth of traffic necessitated its replacement with a modern structure, and the present pin-connected spans were built about the old tubes without false-work, after which it was necessary to cut out the numerous rivets in the old tubes before they could be removed. A percussion rock drill was rigged up, provided with a cutter in place of a drill, and was used with great success in removing the rivets.

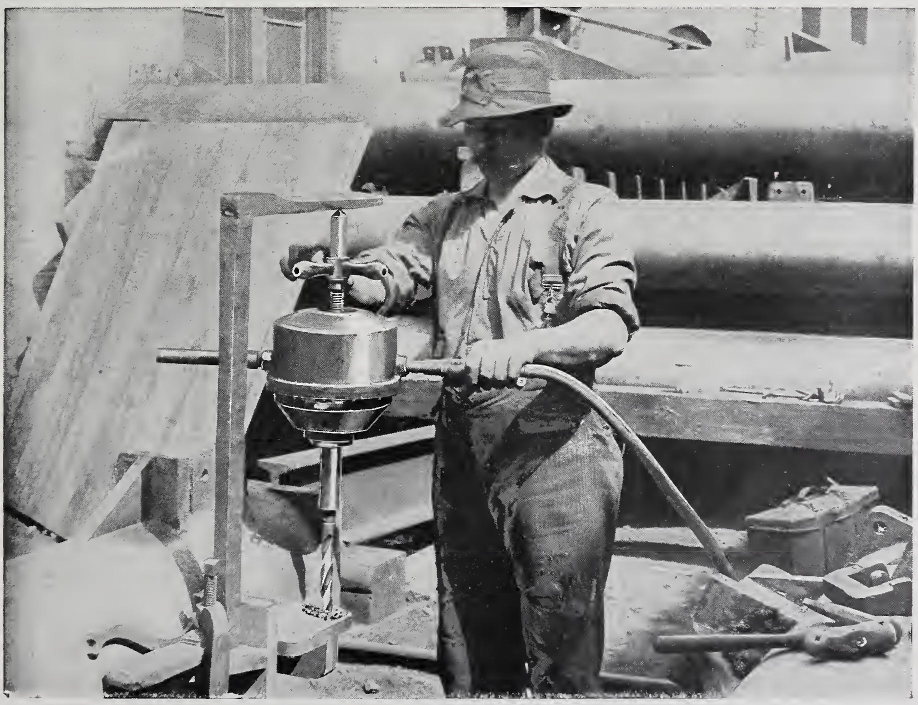
Enough has here been told of the use of machinery in bridge erection to show the extent of the tendency to do away with hand work, without mentioning the use of many other tools, which might, with propriety, be termed machines, and which are every year being added to the erector's outfit.

After the erection of the bridge, the painting remains to be done before the work of construction is completed; and while painting machines have not met with a warm reception in this field, on account of the great waste of paint in

painting latticed members and small bars, certain modifications in the method will, doubtless, be made to overcome this. The machines most widely used are on the same principle as the ordinary perfumery sprayer, the air blast pipe passing across the top of a closed can and blowing across the mouth of the paint pipe, which comes up the side of the can from the bottom. Sometimes the surfaces require cleaning before being painted, as is always true in the case of repainting an old structure. This may be done by a rotary wire brush driven by a compressed air motor of similar construction to the air drill. Sand blast machines have also been used with great success for cleaning off old paint and rust.

Five old bridges on the Boston & Maine Railroad were recently cleaned with sand blast machines, a pressure of fifteen pounds per square inch being obtained by using a gasoline compressor. With the metal cleaned bright, it was necessary to apply the paint promptly, as rusting began quickly. There was some trouble with the sand blast from moisture, but with very dry sand and the exercise of care this was overcome.

There are many items which go to make up the cost of bridge erection. First, there is the character of the work, which may be controlled by the designer, so as to make erection easy and reduce its cost. Next, there are the weight per lineal foot, the length of span and the height of false-work. Where these are a maximum so as to require extensive false-work, it becomes necessary to reduce the cost of its construction by carefully designing it, by employing machine tools in its construction, such as pneumatic wood boring tools and the like, and by carefully working out a scheme for its erection. Then there is the actual cost of handling and completing the metal work, which may be reduced by employing the machines described and by devising new ones. The painting is also a very important item to be considered; and, lastly, there are the conditions at the



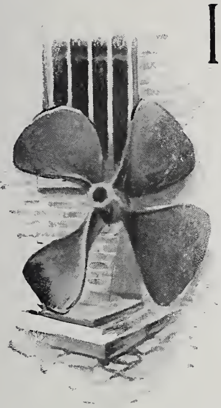
A COMPRESSED AIR PISTON DRILL. MADE BY THE CHICAGO PNEUMATIC TOOL COMPANY

A PNEUMATIC HAMMER DRIVING ⅞-INCH RIVETS ON CHICAGO ELEVATED RAILWAY. MADE BY THE CHICAGO PNEUMATIC TOOL COMPANY, CHICAGO

site and the condition of the weather. Some years ago the writer constructed an empirical formula which contained functions of all these various items and which gave very rational results for the cost of erection; but it was more useful in pointing out the portions to attack to bring about a reduction of erection cost. Indications point to still greater improvements in erection tools in the near future than in the past, and much of it will, doubtless, be brought about by the adoption of electric devices which are used in other kinds of work, and in the application of electricity to new uses.

STEAM PIPING ABOARD SHIP

By Chief Engineer A. B. Willits, U. S. N.



IN one of a series of "object lessons" contributed to the transactions of the American Society of Naval Engineers, the writer recently took occasion to emphasise the fact that the most difficult feature to satisfactorily arrange in the machinery plant of a steamship is that of the piping, and particularly the portion of it which undergoes considerable change in length due to the temperature of the steam or hot water which it is required to convey.

With steam plants on shore ample space is primarily allotted in which to install piping of ideal simplicity and efficiency, and only culpable ignorance can occasion serious mistakes in the installation; but in the case of a steamship, and notably of a warship, the conditions are so entirely opposed to an easy solution of the problem as to make it necessary to give the closest study to the plans in order to avoid defective and even dangerous arrangements. Simple and direct leads are here seldom possible, as where the limit of machinery space is confined to the least number of cubic feet in which the apparatus can be effectively operated, and where overhead room is most meagre and rigidly blocked by a protective deck at about the water-line, it is obvious that pipes connecting distant terminals must frequently be tortuous, and the systems involved and complex.

The importance of properly providing for the expansion of the steam pipes in particular is the one detail in the piping problem to which the writer would here direct attention. It would seem that the study of all the conditions bearing upon such an evidently essential attribute to an efficient plan would take precedence of many other engineering problems about which we read much; yet, strangely enough, this is not the case, and while the science of steam engineering is rapidly advancing on all other lines, the disposition of the steam pipes in marine work appears to improve but slowly, and we hear continual complaints of really avoidable defects in both the lead and accessibility of these conductors, as well as in the actual manner of construction.

True it is that few real casualties force immediate remedial attention to the matter, but all seagoing engineers know that frequently more mental distress and manual toil are involved in the care and keeping of the pipe joints than in all the other work connected with the operation of the engines and dependencies. It is true also that enormously greater stresses are constantly being put upon castings and joints by lack of provision to properly accommodate the expansion of these pipes than was ever calculated for in the design. This, up to the point of rupture, is seldom evidenced, save in leaky joints which will not keep tight

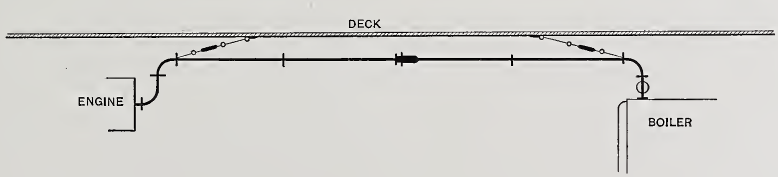


FIG. I

despite the most skillful attention and frequent remaking. How many of us there are who have met with these troublesome joints! Sometimes it is a three-branch casting, fitting all three flanges of connecting pipes perfectly when cold; but when all the pipes are

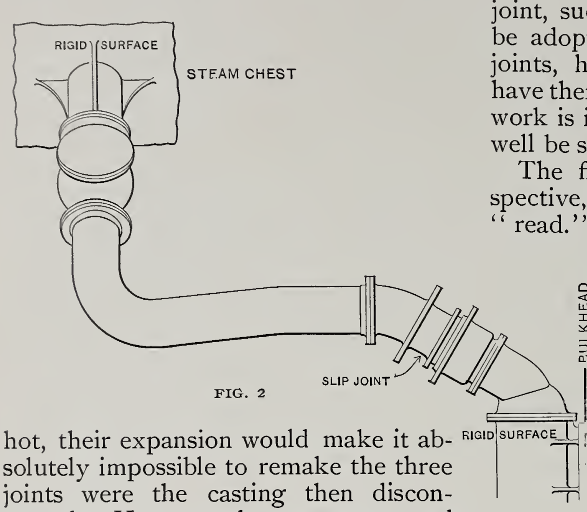


FIG. 2

hot, their expansion would make it absolutely impossible to remake the three joints were the casting then disconnected. Hence, under steam great and abnormal expansive strains are brought on the connections, producing weeping and leaking until, perhaps, a crack in the nozzle points to the true cause of the trouble.

Of course, the ideal steam lead is short and direct, and has the two extremities anchored towards each other, while between the anchors are placed proper slip-joints which can accommodate all increase in lineal dimensions. (See Fig. 1.) But where this system cannot be followed we must not trust to bends and crooks to take up the expansion satisfactorily. Long loops provide, of course, a flexibility not found in short bends, but even at the best this method brings side strains on the flanges and castings at elbows and bends which are forever tending to cockbill flanges and make joints difficult to keep tight, if they do not do more than that, by overstraining these parts. A good slip-joint in the line of greatest expansion, used in connection with "anchors" at such points as will compel accommodation by these slip-joints, is a necessary part of efficient piping, except where a trunnion joint, such as adopted at Yarrow, can be adopted. Where to place the slip-joints, however, is as important as to have them, and an actual case in modern work is illustrated in Fig. 2, which can well be studied as a bad example indeed.

The figure is drawn in partial perspective, scarcely usual, yet most easily "read." Conceive a pressure of 160 pounds per square inch in this 15-inch pipe! Imagine then the elongation due to expansion by the heat, and observe the difficulty in compelling the slip-joint to take this up! Every tendency is for the pipe to spring that much away from the slip-joint, the steam pressure on the elbow (projected area of pipe) assisting it. This pressure, acting at the leverage it there has from the elbow to the steam chest,—about 3 feet,—brings an enormous strain on the casting at the steam chest,—a strain never intended or calculated for, so that, as a result, a crack at the casting might well be expected, and this, in point of fact, came about. To make matters worse, the slip-joint bolts had no shoulders to prevent extraction movement of the joint, being instead provided with stiff springs to resist such action; but these springs failed to meet the expectation of the designer. This slip-joint is faulty in other ways, not being in the proper part of the pipe. This will be evident to any one who will sketch in an imaginary outline of the pipe, increased in all lineal directions by the approximate expansion.

Current Topics

It is not so long ago that some enterprising genius suggested that, for quickly stopping vessels at sea when in danger of collision, a form of marine brake might be used which, in its essentials, should consist of large wings or vanes, hinged to a ship's sides below the water-line, folding closely to those sides when not in use, but capable of being swung out at right angles when needed, in which position their resistance to the ship's forward movement would be instantaneous and highly effective. A few discouraging attempts were made with a contrivance modelled somewhat after this pattern, but it is interesting to recall that more than thirty years ago substantially the same idea was embodied in a patent for a railway train brake, granted in Great Britain. The brake proper in that case consisted of a large vane, extending across the roof of a railway coach, and so hinged that it could be raised to an upright position by means of ropes and a large nut travelling along a screw, which latter could be turned as desired by a train attendant. The vane, in its upright position, of course, added in a more or less appreciable degree to the atmospheric resistance encountered by the train, and upon this the theory of its action was based. With over a quarter of a century's progress in railway brake development to look back upon, this early winged contrivance seems like the outcome of a childish fancy, but even at the time of its proposal there appears to have been no evidence to show that it was ever put to trial.

Comparatively speaking, American industrial establishments may be said to have thus far suffered little from trade union tribulations, and that species of workingmen's persecution which has, for several years past, been inflicted more or less successfully on British employers of labour and which, in the future history of nations, might be fittingly characterised as uniquely British, has been almost unknown in the United States. The one-man-to-a-machine policy, for example, one of the pet schemes of the British trade unionist, a goodly share of the unreasonable demarcation troubles, and various other manifestations of trade union tyranny and nonsense which have flourished in Great Britain, have hitherto had no conspicuous place in differences between capital and labour in America, so that it has become a question of importance as well as interest why this should be so. To one of the world's brightest scientific workers the general statement was attributed some time ago that it is in the variety of foods partaken of by a nation that one should seek the explanation for that nation's mental superior-

ity over others; and possibly, reasoning on a similar basis, one might ascribe the admitted mechanical ingenuity of Americans to the fact that, as a nation, they are made up of a mixture of people of various nationalities, each one contributing his particular quotum of useful knowledge and mechanical skill to the common national fund, while his tendencies towards such evils as those of rabid trade unionism can gain little hold with the prevailing lack of cohesion among the different nationalities represented in the different workshops.

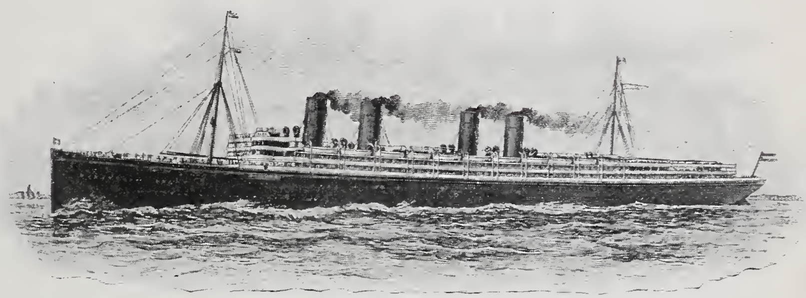
REFERRING to this mixture of nationalities, it was pointed out recently in *Engineering* that while one is apt to look upon all the people in the United States as Americans, and while, so far as citizenship is concerned, this is fairly true, they are, in blood, far from being one race. It would be an interesting field of inquiry to investigate in how many generations a family of, say, pure Polish blood will lose the characteristics of its origin, and become blended in the general mass of the surrounding people. Whatever the answer may be, it is certain that a relatively considerable time will be required to effect the change. At present the number of foreigners in America is far greater than is usually imagined. For instance, at the Pullman Works, out of 7152 mechanics, labourers, and others there are no less than 4246 who were born in other countries than the United States,—that is, 58 per cent. Scandinavia furnished the larger portion of the immigrants, 1489, or 35 per cent., the bulk of them being Swedes. The British Empire sent 919, of whom 273 were Canadians and 205 Irish, while 303 were English. Germany (including Austria) comes next with 817, nearly all North Germans. There are 616 Dutch, which is a very large contingent, when we remember the size of their native country. The Latin races make a very poor show, if we except Italy, with 106 immigrants. France sent 9, Belgium 11, and Switzerland, which is not wholly Latin, 20. The Frenchman has no desire to emigrate; the existence of a colonial party in the legislature satisfies his aspiration in that direction. The Belgian who wants to emigrate goes to France to fill the vacancies caused by the dwindling of the population. The Swiss in a foreign country becomes a hotel porter, and eventually a hotel proprietor, rather than a mechanic. The remaining 259 men at Pullman are of eight nationalities, 114 being Poles, 78 Russians, 32 Bohemians, and 22 Hungarians. A classification of this working force, made recently, shows that there are 250 highly skilled men, capable of original work, 3086 first-class mechanics, 2015 fair workmen, and 1801 labourers. Nearly one-half, that is, 3242, reside in Pullman, the wonderful town brought into existence by the energies of the man after whom it is named. The average length of time that the work-people have been employed is stated to be 6¼ years. Were it not that these data are from an official publication one should feel doubtful in giving currency to this statement. It is a wonderful testimonial to the satisfactory relations which exist between the company and the work-people, and shows that the energy which is supposed to mark the mechanic in America does not necessarily cause him to wander from shop to shop. When he finds a good master he keeps to him.

PIPE lines for gas, water, steam, and oil long ago demonstrated some of the attractive possibilities of the pipe-line method of fluid transportation and made it familiar to all, with evidences of it abounding in every-day life. And yet one is impressed with a tinge of novelty in a recently circulated newspaper waif which tells of a twenty-five-mile pipe line for conveying sugar-house syrup. At Springvale, Utah, U. S. A., it appears, there is a plant for slicing sugar beets and extracting the sugar-laden juice by diffusion, and this, with its impurities, is then "piped" to a beet sugar factory at Lehi, there to be treated and refined by the usual processes. In-

quiring further, however, it is learned that the same system of piping sugar juices has been in vogue in France and Germany for a number of years, and in the latter country, too, pipe lines have been used in potteries to carry much-thinned clay paste from one department to another.

An ingenious construction of rheostat for absorbing an output of 400 kilowatts, used in testing the generators in the station at Nancy, France, was recently described in *L'Electricien*. The rheostat consists of galvanised iron netting ordinarily used in protecting the underground distribution cables, the particular advantage obtained in using this material apparently being the enormous radiating surface per unit cross-section. A strip of this netting about 11 inches wide, composed of sixteen strands of galvanised iron wire with a cross-section of about $\frac{8}{100}$ of a square inch, the whole strip being 180 feet long, absorbs 500 ampères at 240 volts, the strands remaining at a temperature below that of the fusing point of lead.

With the launching last month of the Hamburg-American Line steamer *Deutschland* at the yard of the Vulcan Shipbuilding Company, at Stettin, Germany, another monster passenger carrier for the trans-Atlantic service has been added to the already pretentious list of such vessels. The *Deutschland*, in point of size, is second only to the White Star liner *Oceanic*, measuring somewhat over 686 feet in length, against the *Oceanic's* 704 feet, while her width is 67 feet; depth, 44 feet; and displacement about 21,000 tons. There will be twin screws and engines of 35,000 indicated horse-power with which the vessel will be expected to attain an average speed of 23 knots, thus making her the fastest passenger vessel afloat. Aside from her features of engineering interest, she will appeal to voyagers with promises of luxuries even greater than any hitherto offered aboard ship. In addition to the large dining-saloon, ladies' parlour and smoking-room, there



THE NEW ATLANTIC LINER "DEUTSCHLAND"

will be a play-room for children, and a gymnasium, where old and young may seek recreation and relaxation from the routine of ship life. A grill room, on the promenade deck, where one may have a broiled steak or chop, and other dainty dishes, will be a feature that will appeal strongly to many travellers. The staterooms will contain everything conceivable to enhance the comfort of the passengers, and a number of rooms will be arranged for the sole occupancy of those who would have a room to themselves. Bilge keels will help to reduce rolling of the vessel to a minimum, so that even the terrors of seasickness will be diminished.

Once a workman becomes accustomed to, and familiar with, a labour-saving appliance, he will occasionally use it in a manner bordering on the ridiculous. It may be that he will em-

ploy the device to save himself the least exertion, and it may be that he will utilise it in a task which is absolutely useless in itself. The convenience of the workman may be, and often is, the essential consideration, and if he can avoid a little extra exertion, he will do so in the majority of cases. This he will do even if he has to employ a giant to do the work of a pigmy. An illustration, given in the *Iron Age*, occurred not long ago in a well-known shop. An old helper was sweeping the floor. Directly in his path stood a machine weighing ten tons, boxed and ready for shipping. The sweeper thought his job would be a trifle easier if that box were out of his way. He, therefore, asked the travelling crane operator to move it back a few feet to a clean part of the floor. He did so, and the old man proceeded with his sweeping, evidently feeling relieved that his work had been made so much easier. The sweeper had no idea that his request was at all out of the way; neither did the crane operator. The incident attracted no attention whatever, except from the manager, who chanced to see it. He said that it was the best illustration of the real value of a labour-saving machine that had ever come under his notice.

It has been frequently said that British machine tools are inferior to those of the United States, and within certain limits there is, no doubt, much truth in that observation. British tool makers and British tool users, for example, as the London *Engineer* puts it, have been very conservative. Designs which fathers found good, sons have commended. The workman, too, has been averse from progress. But both users and makers are waking up. Several English firms have been working away quietly at the construction of modern tools, and they are beginning to reap their harvest. There are, moreover, signs that the British maker, having learnt his lesson from his American cousin, will some day beat or teach his master. American makers are already giving up the inverted V bed, which was at one time so popular with them, and are following the British example in providing a large flat rubbing surface. Collaterally with that improvement they are providing means for preventing the tilting or rocking of the slides and turrets, which were wanting in older machines. Probably they will also ultimately give up the soft spindle running in soft brass or Babbitt metal, and adopt the British method, and use a hard steel spindle in the hardest bronze, both lapped or ground dead true. These features are essentially British characteristics; they make for stiffness and long life. At present it may be said with honesty and fairness, so concludes the *Engineer*, that where British makers have followed American general designs or principles they have made better machines than any that come into Great Britain. The time is coming when they will do their own designing, and do it well.

SIR BENJAMIN BAKER, K. C. M. G.

A BIOGRAPHICAL SKETCH

WHILE Sir Benjamin Baker has designed and advised upon many engineering works of great importance, including, among others, the ship railway across the Bay of Fundy, several subaqueous tunnels, the barrage of the Nile, in brief, most of the great engineering projects of recent years, his name will probably always recall more particularly the Forth Bridge which has been classed as the greatest engineering structure of modern times, exceeding not only all other bridges in reference to length, dimen-

sions, weight, and other standards of greatness, but also excelling all other structures in its remarkable adaptation of means to ends, and in the unique character of the operations necessary to its accomplishment.

Sir Benjamin Baker was trained first in a South Wales ironworks, and then in the engineering offices of Sir John Fowler, with whom he was associated afterwards in carrying out the Forth Bridge enterprise. The varied character of the work that came to be discharged in the office of Sir John Fowler afforded him a large and valuable experience in almost every branch of engineering. He had, of course, done a great deal of excellent work before ever he had any knowledge of the Forth Bridge; he had written a book on hanging span bridges, which was published in England, America, Germany, and Holland, and had prepared and read before one or the other of the various engineering societies papers on different subjects connected with engineering, which secured for him the full confidence of the profession. More especially had he acquired a reputation as a bold designer of novel constructions and as a patient and cautious experimenter on the properties of materials of construction, with the view of ascertaining and determining their fitness for different purposes.

About twenty years ago, in order to determine whether engineers and manufacturers had arrived at a certain definite quality for the use of steel in tyres and axles, Sir Benjamin obtained half-a-dozen pairs of tyres and axles from as many of the leading British and other makers and submitted them to a series of tests which gave startling and unsatisfactory results. Not only was there no uniformity in the quality of the steel supplied by the several makers, but even the two tyres made by the same maker gave, as a rule, widely different qualities. The conclusion drawn by Sir Benjamin from his experiments was that it would be imprudent on the part of an engineer to leave the quality of steel supplied for either tyres or axles to the discretion of a manufacturer, or to forego the most rigid system of inspection. He found that a sample of steel may be cut from a tyre or axle, and be tested with perfectly satisfactory results, as regards tensile strength and elongation, and yet that the tyre, as a whole, may be frail under moderate shocks, either on account of the steel being inferior, or from its want of uniformity.

The attention which Sir Benjamin Baker had given to the principles of bridge construction, long before he had any thought of the Forth Bridge, is illustrated by some of his remarks at the Institution of Civil Engineers, during a discussion on the erection of iron bridges. In this case he showed that bridges had been erected by building out at least two centuries before it was attempted in modern Europe, Turner, in his history of his embassy to Thibet, having illustrated and described an ancient bridge on the cantilever and central girder system which had been so erected. Sir Benjamin also found that in 1810 a Mr. Pope proposed to construct a cantilever bridge of 1800 feet span across the East River, at New York, which was to be erected by building out. A more practical undertaking, however, was the railway bridge across the River Dal, in Sweden, built by Mr. E. Hutchinson, of Darlington, having a centre span of 208 feet, which was built out, without staging or auxiliary girders. In designing the Forth Bridge, Sir Benjamin Baker arranged to build the projecting cantilevers on each side of the central towers, and many novel and ingenious features were introduced by himself and Sir W. Arrol for the safe erection of the structure.

The work of bridging the Forth, although not actually commenced until the month of February, 1883, and not completed until seven years afterwards, had often been proposed. Plans for the purpose are said to have been actually drawn up as long ago as 1810. The next practical step appears to have been taken in 1879, when Sir Thomas Bouch prepared a plan for a suspension bridge, which had virtually been adopted when the disaster to the Tay Bridge caused the proposal to be given up. As early as 1870, however, Sir Benjamin (then

Mr.) Baker had given his estimate of the weight of steel required for a double line railway bridge of 1700 feet span, and advocated the system of construction subsequently adopted at the Forth on the grounds of economy, rigidity, and facility of erection. The design of Sir John Fowler and Mr. Benjamin Baker was ultimately adopted, under powers obtained in 1882.

For the purposes of the determination of the qualities of the materials to be used in the construction of the Forth Bridge, Sir Benjamin Baker carried out many experiments on steel, resulting in the decision to use material of a higher tensile strength than was considered admissible either for ships or for boilers. As at least one-half of the steel employed on the Forth Bridge is in compression, it was important to gain an increase of resistance without any sacrifice in the facility of working and safety. Hence it was urged by Sir Benjamin that, if practicable, the material most suitable for the compression members of such a structure as the Forth Bridge would be 34 to 37-ton steel, which had been previously squeezed endwise in the direction of the stress. Experiments were also carried out under Sir Benjamin's direction on the resisting power of different classes of iron and steel to repeated bendings, on the effect of sheared edges on fracture, and many other problems that had to be solved in so serious an undertaking. During the seven years that the Forth Bridge was under construction there were probably no more laborious or anxious men in the United Kingdom than its engineers and contractors. Sir Benjamin was on the ground late and early; he had to decide and solve every new difficulty as it came up; he had practically no experience of similar structures to guide him, which rendered his work not less scientifically accurate, perhaps, but certainly more practically difficult; and he had to work out for himself many matters that were settled for the first time in the drawing-office at Westminster or at South Queensferry while the bridge was in course of erection.

On the occasion of the opening of the Forth Bridge, on the 4th of March, 1890, the Prince of Wales stated some facts that are worth recalling. The extreme length of the bridge, including the approach viaduct, is $1\frac{1}{5}$ mile, and the actual length of the cantilever portion of it is a mile and twenty yards. The extreme height of the steel structure above high-water mark, and above the bottom of the deepest foundation, is 452 feet. The wind pressure provided for is 56 pounds on each square foot of area, amounting in the aggregate to about 7700 tons of lateral pressure on the cantilever portion of the bridge. The surface of the bridge requiring to be painted is about 135 acres. About eight million rivets have been employed, and some 42 miles of bent plates have been used in the tubes. The total weight of steel in the bridge is about 51,000 tons. The total expenditure on the bridge and approach railways up to the date of its opening was £3,177,206.

In recognition of his distinguished work as an engineer, at home and in the colonies, Mr. Baker received the honour of K. C. M. G. after the opening of the Forth Bridge in 1890. He was also elected to Fellowship in the Royal Society. He was made a member of the Council of the Institution of Civil Engineers before his connection with the Forth Bridge, and later filled the office of president. In 1885 he was chairman of the Mechanical Section of the British Association, and subsequently received the Poncélet prize of 2000 francs from the French Academy of Sciences. On the occasion of the tercentenary of Dublin University he (with Lord Armstrong) was made Honorary Master of Engineering. He is also an honorary member of the American Society of Mechanical Engineers, and of many other institutions.

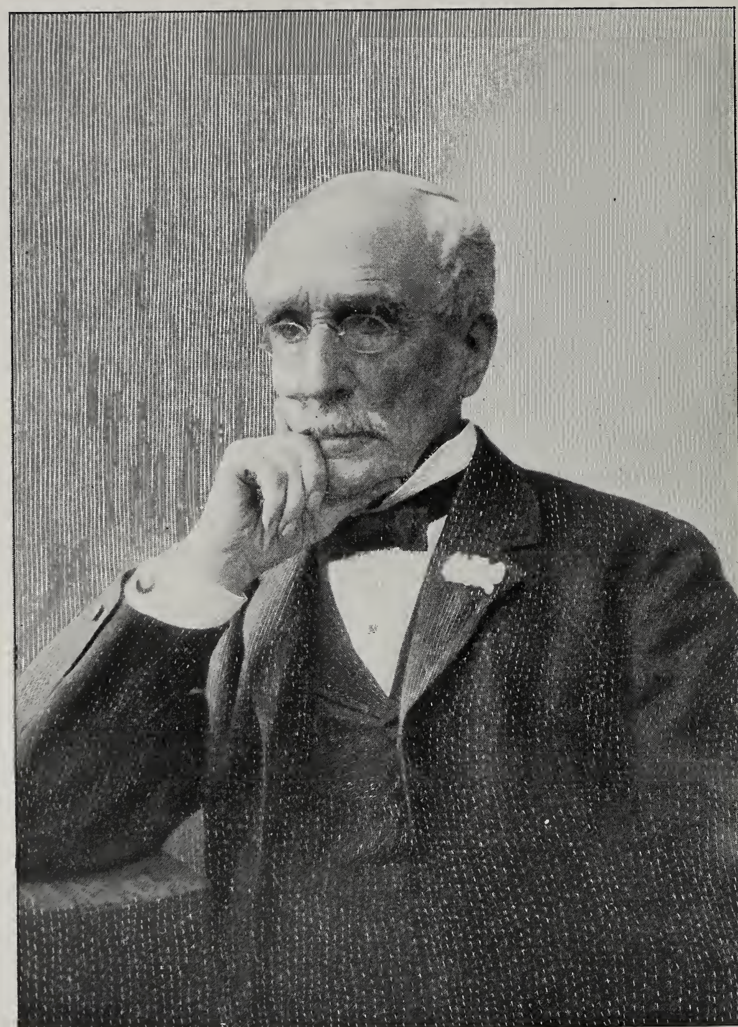
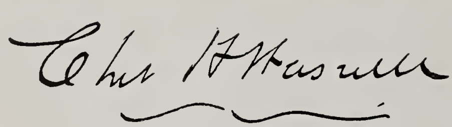


PHOTO BY PACH BROS., NEW YORK.



THE OLDEST ENGINEER IN ACTIVE PRACTICE

SEE PAGE 438.

CASSIER'S MAGAZINE

Vol. XVII MARCH, 1900 No. 5

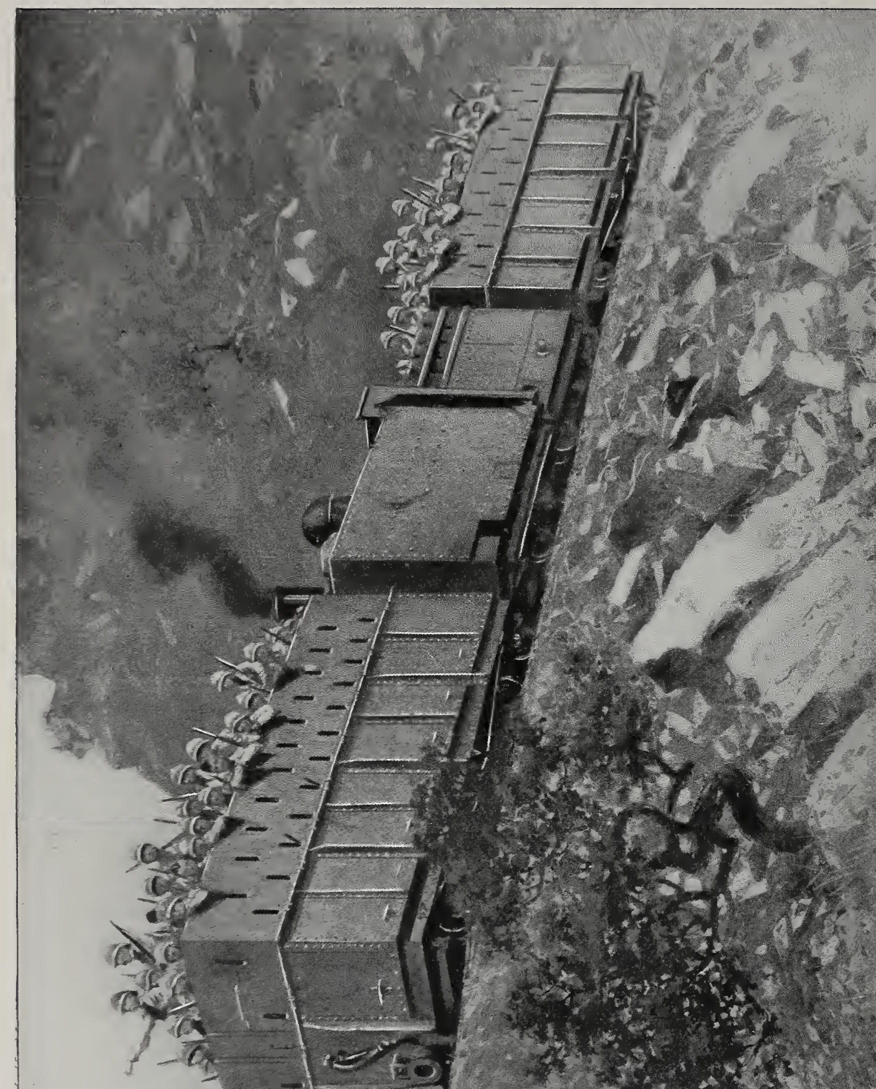
WAR MECHANISM IN SOUTH AFRICA

By George Ethelbert Walsh

ZULU WARRIORS OF EARLIER CONFLICTS

FROM an engineering point of view the war now being waged in South Africa will prove of particular value because of the use on a large and practical scale of a number of modern inventions for military purposes. It was expected that when Great Britain, Germany, France or Russia next engaged in a war of any considerable size the work of testing modern war inventions would devolve upon the engineering department of the army, and the fact that the first practical experience with these appliances should fall to the lot of the British Army is a matter for congratulation. No more efficient engineers ever accompanied an army to the field of battle than those who are working in the British Army in South Africa, and the scientific world will be satisfied that the utmost practical test will be made by them of the various instruments and war machines placed at their disposal. The results of these tests will help to settle any disputed or questionable point about the relative practical value of the modern war appliances.

Ever since the Franco-Prussian war mechanical engineers have been labouring to produce instruments that would be so destructive that war would be rendered almost too sanguinary for civilisation to tolerate it. Guns have increased in size and efficiency, and ammunition has been doubled and trebled



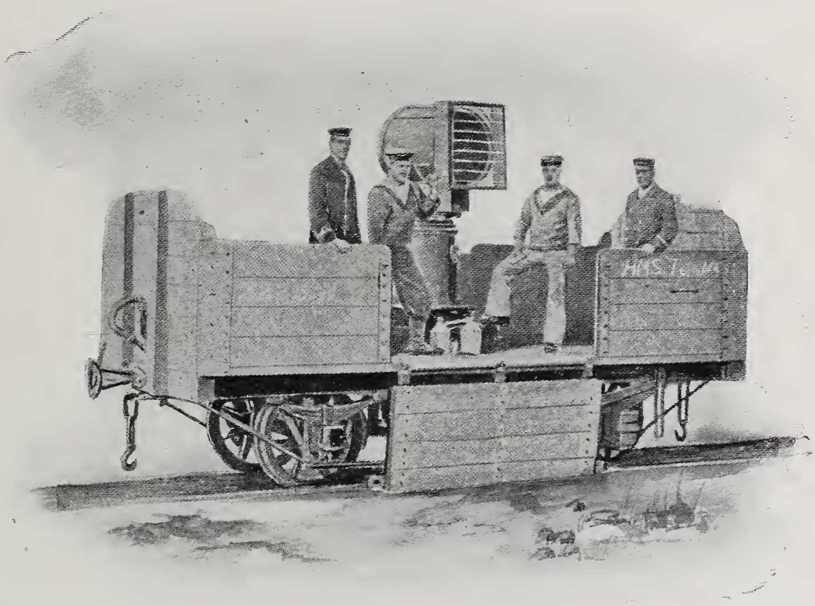
BY PERMISSION OF THE ILLUSTRATED LONDON NEWS

AN ARMOURED TRAIN SORTIE FROM LADYSMITH

in its destructive power. The common shrapnel shell of 1870, used in the Franco-German struggle, that burst into about forty pieces, has been improved so that it explodes into about ten times that number, and the old powder-filled bomb of that date has been changed for one charged with high explosives of tremendous effect. Likewise the rapid-firing field pieces, Maxims and Hotchkiss guns, and others, have multiplied the number of shots they can fire in a minute by nearly twenty. In the matter of range the same improvement is noted, both in the siege guns and small arms. In 1870 the long-calibre rifles, charged with comparatively weak powder, could kill only at a comparatively short distance, but the rifle of to-day has a point-blank range of about 660 yards, and kills at a distance of over two miles.

These improvements in the efficiency of the small and large guns have been demonstrated facts, and needed no practical test to make them apparent. An army provided with such deadly instruments of war could perform wonders in execution if the soldiers were trained to use them properly. Their improvements were almost perfect, and there was no question in the minds of military experts as to their practical efficiency if the men behind the guns were properly skilled and trained. In the use of these arms the present war demonstrates the markmanship and skill of the soldiers more than the efficiency of the weapons. The test is one of men and not of mechanical invention.

But there are other war appliances whose value is not so readily demonstrated in times of peace. Under proper conditions on practice grounds they worked satisfactorily, but in the field, where a rough, broken country was occupied by an enemy, it has long been a question whether the same desirable effect could be obtained. South Africa, with its ridges of mountains, its wide, turbulent and almost unfordable rivers, and its long stretches of foodless veldts and rough country roads, affords a field for military operations on a scale that is dear to the heart of a born commander. There is room for a thousand and one



A SEARCHLIGHT FROM H. M. S. "TERRIBLE" GOING TO THE FRONT FOR SIGNALLING USE

military manœuvres that are known to experts. In such a country many of the modern military appliances should

A MAXIM GUN ON A LIGHT TRIPOD

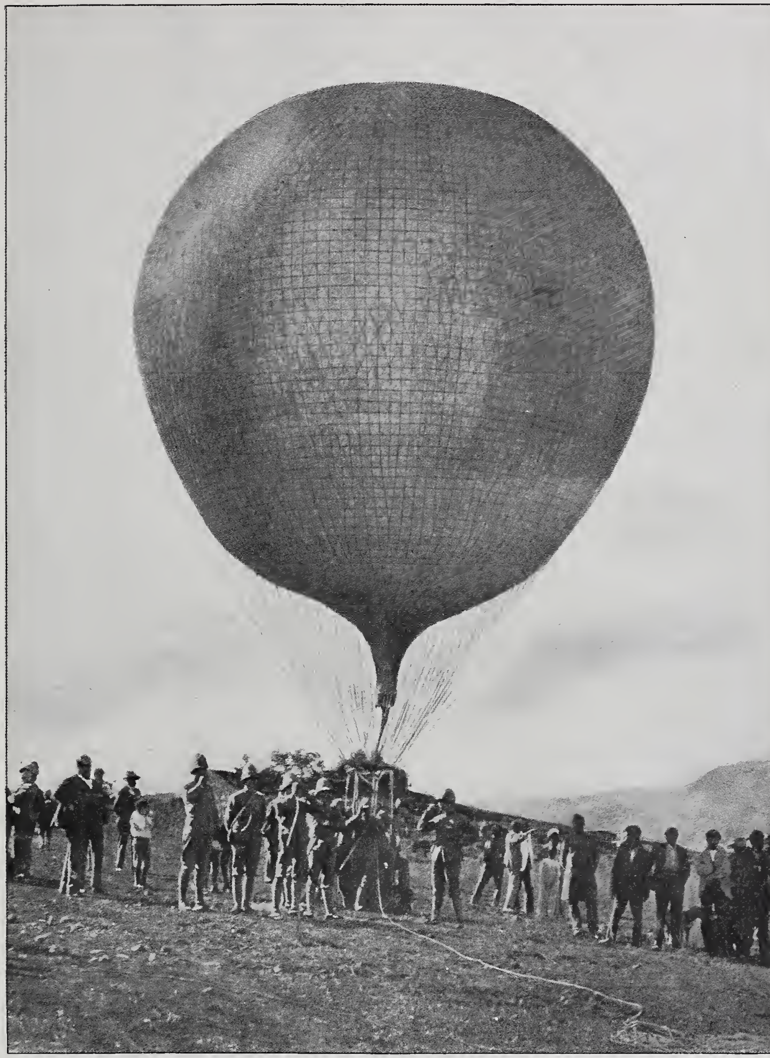
be at their best, and they have already been employed to such advantage that when the war closes the lessons will be inevitable. Inventions will be discarded or more generally adopted, according to the nature of the conclusions reached.

The armoured train is one of the instruments of war that has received a severe test in South Africa, and the reconnoitring performed by these engines of modern warfare has served to call more than passing attention to the subject. Credit has been given to Admiral Fisher, of the British Navy, for the first use of the armoured train in actual war, when, in 1882, he covered a locomotive with boiler plate and equipped cars, similarly protected, with field guns and put them to effective practical use.

But the germ of this idea goes back further than 1882. When the Germans closed their vise-like grip upon Paris, the French made frequent sorties from the city, and in many of these attacks they were assisted by field guns mounted on waggons and carriages. Later, they were mounted on railroad cars, which were protected in their vital points against the enemy's guns. They could hardly be called armoured trains such as have been used in South Africa, and whether Admiral Fisher got his notion of an armoured train from the besieged Parisians is, therefore, an open question.

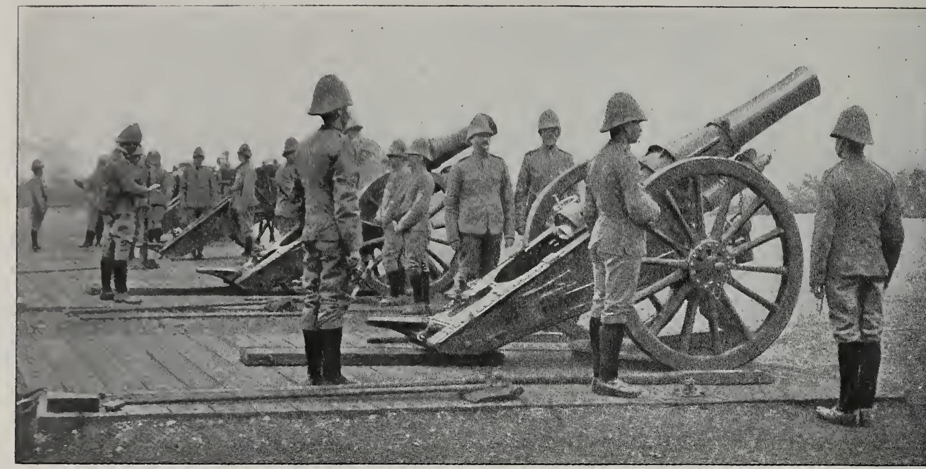
Since 1882 most of the military pow-

A LIGHT MAXIM GUN ON TRICYCLE MOUNTING



THE BRITISH MILITARY OBSERVATION BALLOON AT LADYSMITH

ers of Europe have been experimenting with armoured trains. Great Britain, as if anxious to sustain her reputation of first having invented the new instrument, has steadfastly kept the lead, and has now probably the most complete and efficient armoured trains in the world. The best that the British Army possesses is the engine and train of the First Sussex Artillery Volunteers, and this is far superior to the hastily-constructed trains that have previously been in service. The model train was made from special designs for war purposes. The protected engine carries a Maxim gun, and the protected cars have heavy field-guns operated by machinery, so that any part of the surrounding country can quickly be covered. Arrangements are made to compensate for the recoil, and also to give steadiness and stability to the cars. This latter is accomplished by an arrangement for clamping the truck to the rails by strong screw clips whenever the gun is fired. There are also several steel-



BRITISH 6-INCH HOWITZERS

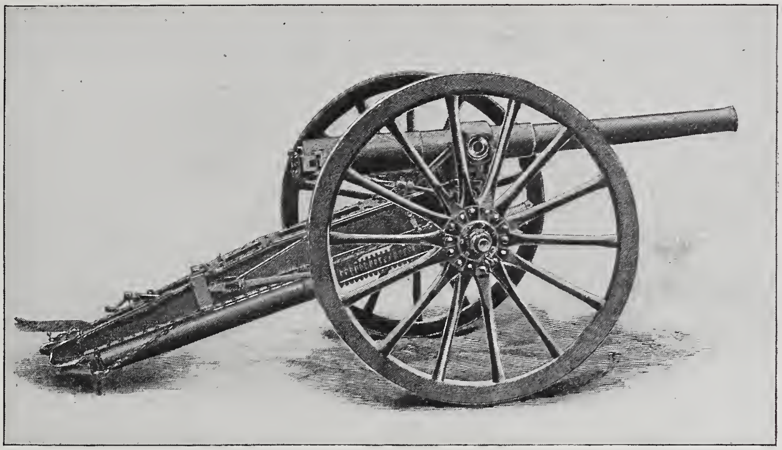
plated vans accompanying the train in which horses and soldiers can be safely conveyed.

The armoured train, it has been stated, was never intended to be used except in conjunction with cavalry, and it was due to lack of support of mounted troops that several of the disasters to the hastily-constructed trains in South Africa occurred. In co-operation with a strong force of cavalry the armoured train is a formidable weapon, but without the help of mounted troops a small quantity of dynamite might be used to destroy the road-bed in the rear and wreck the train. In spite of the lack of all cavalry support, however, this type of movable fortress performed notable achievements in South Africa, and in the sorties from Ladysmith and Kimberley it was the chief implement that forced the Boers back. With machine guns and field pieces the moving train becomes a valuable offensive apparatus, being able to move up close to the enemy's lines or retreat to a point beyond the range of small arms. The rapidity with which the train can change its base of action renders it a difficult object for the batteries of an enemy to hit, and almost the only way to defeat its operations is to wreck or derail it; then it becomes a helpless target for long-range guns.

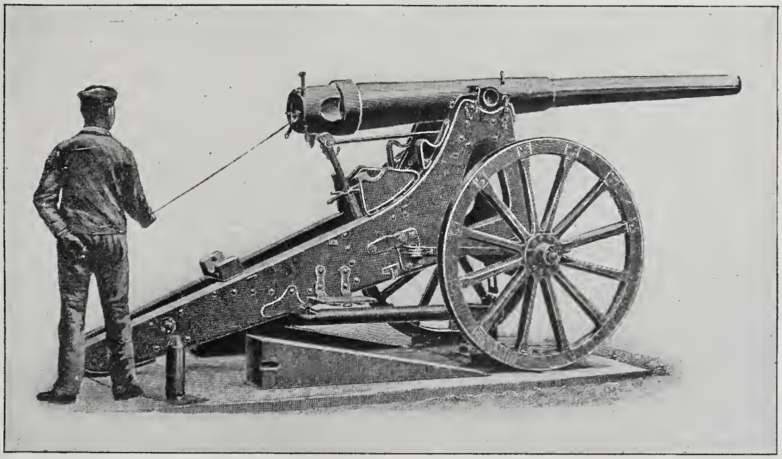
The question of armoured motor cars which could travel over an ordinary road or level stretch of country has also received some attention in the South African conflict. Several cars were extemporised hurriedly for this purpose, but they proved of little use in a rough country, and as commanders do not always choose a level space for their battles, the armoured motor car is still a war machine of doubtful efficiency. In the mountainous regions of South Africa it is hopelessly inadequate for effective service, and, with the exception of a few isolated instances they were never seriously taken up.

When the war broke out the British War Office negotiated with Marconi's representatives for wireless telegraphic outfits, and a number of apparatuses were dispatched to the scene of the conflict as quickly as possible. But for some reasons, not yet explained, the wireless telegraphy system has not performed the efficient services expected of it. This may have been due to the lateness of getting the outfits to their destination and not to any defect in the system or lack of skill in the operators. The cause of this will be determined later when full investigations have been made in the interest of military science. Substitutes for Marconi's system have, however, perfomed work that is worthy of more than passing notice. Some of these were merely hastily-improvised

machines erected by the engineering corps of the army. At Kimberley, for instance, the powerful electric searchlight, which has heretofore been considered of use chiefly on the sea, was impressed into service in a manner that yielded fruitful results. It was first arranged on a high tower for the purpose of watching the movements of the enemy. Then, as the days and weeks passed, and it was known that a relief column, under Lord Methuen, might be expected at any moment, a system of signaling was devised, the operators using the secret code of the army by means of dots and dashes of light. The first word from the beleaguered city was communicated to the outside world by means of this searchlight signal. When the army of relief was twenty and thirty miles away messages were flashed to it concerning the condition of the garrison. The electric searchlight signaling station thus hastily constructed was simple in its operation. By switching the current on and off, the



A BRITISH FIELD GUN



ONE OF THE BOER "LONG TOMS." A KRUPP 10.5-CENTIMETER (4.13-INCH) SIEGE GUN

HAULING SUPPLIES BY TRACTION ENGINE

powerful light was broken up into the desired dots and dashes which formed the telegraphic letters.

At Ladysmith the British Army was the fortunate possessor of one of the modern war balloons, and to this the remarkable resistance of the beleaguered garrison owes much of its success. The observation balloon has been floating over Ladysmith from the first, and by means of it the long-range naval guns have been enabled to hold the Boers at a respectful distance. Not even in the siege of Paris, when the war balloon was first used by the French, nor in the battle of Solferino, when M. Goddard, the French aeronaut, made such a masterly survey of the hills and secreted forces of the enemy, has the balloon's success as a military equipment been more signally demonstrated than in South Africa. Connected with the ground by electric cables and telephone wires, the aerial observers above Ladysmith have been able to watch the enemy night and day. Sudden and unexpected attacks on the city were thus prevented, and in several of the successful sorties from the city the time and position were selected on the advice of the balloonists. During the bombardment of the city the position of the Boer batteries was located by the aeronauts, and the British naval guns were thus enabled to direct their fire upon the enemy with good results. It has been commonly said that the naval guns from the cruiser *Powerful* saved Ladysmith, but it might as truthfully be added that the balloon made them available. The effect of the shells could never have been ascertained had no

SIGNALLING WITH A HELIOGRAPH

balloon been in use. The signaling from the balloon to the army of relief under General Buller has also been a feature of the success of this instrument of modern war. The system of electric balloon signaling used was the invention of Eric Stuart Bruce, M. A., but in operation and effect it was very similar to the improvised electrical tower at Kimberley. At the great altitude attained by the balloon, however, the range of signaling was greatly extended. The long and short flashes of light can be seen more than a hundred miles in the clear atmosphere of South Africa. News from Ladysmith has thus been coming regularly, in spite of the complete encircling of the city by the Boers.

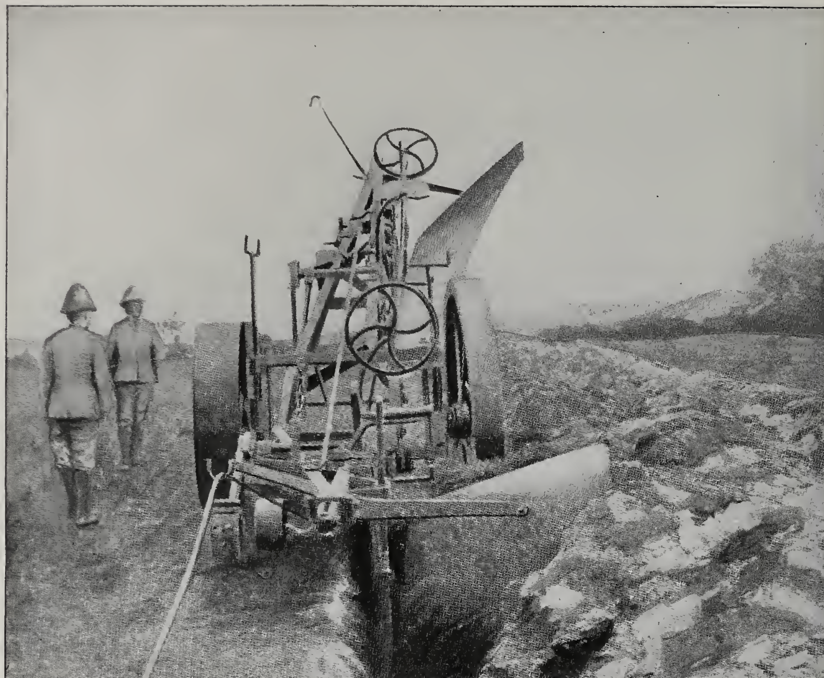
The signal balloon corps attached to the British Army took several observation balloons with them to South Africa, and also materials with which to construct a number of others. They will be used not only for signaling purposes and for observing the enemy, but for studying the topography of the surrounding country. This information is considered of inestimable advantage for an army invading a rugged and mountainous country such as the Transvaal, and the detachment of Royal Engineers engaged in surveying the country have already found the balloon an indispensable adjunct. Maps of the surrounding country are rapidly drawn from the balloon, the details of which are filled in later by personal examination of the surveyors. Thus the balloons enable the surveying to precede beyond the line of skirmishers and outposts instead of in their rear.

But the balloon and electric signaling apparatus have not entirely superseded in service the heliograph, which more than once has been of the greatest service to the British Army, and which the Boers have employed so successfully in the present campaign. The "helio" has flashed many an important message of welcome across the country. It was the "'helio" that sent the glad tidings to Candahar, in 1880, of the approach of a relieving force. Although the latter was nearly fifty miles distant when the first message flashed out of the hazy

A WIRELESS TELEGRAPH STATION

atmosphere, the beleaguered garrison, under Colonel Keyser, took courage, and renewed their efforts to hold out against the enemy.

Likewise in the South African campaign of 1883-5 the British used the "helio" to great advantage. A line extending over 429 miles was then established from the Orange River to Molopole, with twenty-nine stations between the two points. Messages could



A TRENCH DIGGER BUILT BY MESSRS. JOHN FOWLER & CO., LTD., LEEDS, ENGLAND

be transmitted along the entire line inside of half an hour, and in a single day over 3,000 words were sent. The British army then depended almost entirely upon the heliograph for its communications, as the Boers have done in the present war, and in such a rugged, mountainous country as South Africa it is a most successful method of news transmission. The range of the heliograph is enormous, and in the clear South African atmosphere the distance is greater than in most other countries. In the 1883-5 campaign one of the stations was located 42 miles away from the others, but no difficulty was experienced in communicating between them. The heliograph has not been improved much since that campaign, and it works about the same to-day as it did when it was first adopted. It reflects the rays of the sun by means of a movable mirror on and off a distant station, and by adopting the dot and dash method of telegraphing, messages are easily transmitted. The success of the apparatus is partly due to its secrecy. The enemy could stand within a short distance of the point toward which the rays were directed and be unable to discover the signaling light. It is this invisibility of the rays over an extended area that makes the "helio" hold a commanding position to-day when the signalling balloon and electric searchlight are competing in the field.

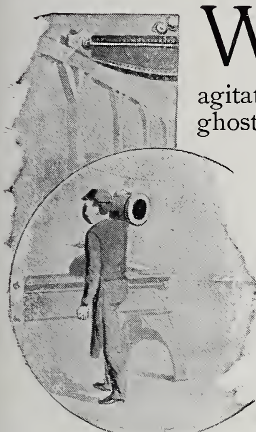
Besides these mechanical appliances the British army is supplied with modern field telephones of the most approved style, carrier pigeons, and the already mentioned Marconi telegraph system. It would seem that with all these methods of communication the different divisions of the army might keep in close touch with one another, and as so much depends upon these "nerves" of the army in a hard campaign over a wide stretch of country their employment must constitute an important feature, contributing a fair share toward the ultimate result.

THE METRIC SYSTEM

IS IT WISE TO INTRODUCE IT INTO BRITISH AND AMERICAN MACHINE SHOPS ?

FROM AN AMERICAN POINT OF VIEW

By Dr. Coleman Sellers



WITH the more or less energetically continued metric system agitation which, like Banquo's ghost, will not down, it seems eminently appropriate to present here at this time substantially the views advanced by the writer nearly twenty years ago in an address before the American Society of Mechanical Engineers. In this it was endeavoured to show that the metric system, *per se*, is not so well adapted to the wants of machinists as the one now generally in use in Great Britain and America, and that its enforced introduction would do harm, rather than good, to the industries of both countries.

Mechanical engineers, of all men using weights and measures, are the ones most eager to adopt what, in the end, will be of most service. To them weights and measures are not abstract ideas, but tangible substances. Engineers make the machines for weighing and measuring, and the result of their use of those machines exists as fixed matter, costing millions upon millions.

To the great bulk of mankind engaged in trade, in buying and selling, in bartering and exchanging, it matters little what system of weights and measures they adopt; it matters little whether they are obliged to use a yard-stick or a meter rod, pounds or kilogrammes, quarts or liters. The cost to them of a change from one to the other is the cost of the few devices needed in weighing and measuring; the *rationale* of the system may never enter their thoughts.

With the machinist the case is different. He must not only possess costly means of measuring and weighing, with a degree of exactness unknown to others, but the results of these weights and measurements are fixed and unalterable. Enormous expenditures on tools, on drawings, on patterns, on everything he uses in making or building his machines are on what is involved in the primary system used in determining weight and size. The product of this expenditure means everything that makes modern civilisation possible. I propose, in this paper, to consider the subject only as it relates to the engineering profession; not in regard to its effect on the grocer, the dry goods man, or on the druggist. I propose to show why after many years' constant use of the metric system of measurement I record my opposition to any enforcing legislation in this direction, because the metric system is not well adapted to the practice of the machine shop.

The system is urged by theorists as a perfect system. All nations, we are told, should adopt it to bring about a desirable unity in weights and measures, even if all cannot be made to speak our language and all cannot be equally good and pious, as measured by some international scale of goodness and piety.

The metric system was legalised in the United States in May, 1866. Some of its enthusiastic advocates later urged its being made exclusive and obligatory. Societies were organised to teach its prin-

ciples to the people, and much money has been expended in publishing, but up to this time few conveniences have been placed in the hands of mechanics to enable them to use it in their calculations. Some years ago (the conditions remain the same to-day) letters addressed to leading publishing houses asking for metric books in the English language, equivalent to those to which we constantly refer, which books are as necessary to us as are our other tools, failed to bring a single favourable answer. What was asked for was some book in which formulæ shall be given in the most convenient form expressible in relation to the metric nomenclature. Many books can be found urging its merits as a system, and the writers of these, in showing (?) that the metric system can be learned entire in, say, fifteen minutes, may think they have done what is needed; but no book yet published in the English language, so far as I have been able to learn, even approximates to what is required. We have nothing like the handbooks published in German. German publishers, in teaching their people, gave, side by side in their almanacs of mechanics, the formulæ expressed in Prussian inches and in meters. When the year 1880 came around they dropped the Prussian inch from these books when it was possible so to do. There are many very good books of tables for the ready conversion of the measurements of one system into the other, but unless an engineer is as familiar with the metric system as with his own they aid him but little. On the other hand, our English work books are many and valuable. The great bulk of literature of primary importance to mechanical engineers is in English and expressed in feet and in inches.

The absence of these help books need not, however, prevent any one familiar with the metric system from using it in his practice. If he can think in the new system he can work in it, too. He can formulate what is directly needful to him if he will take the time and trouble so to do. The absence of these books has not prevented us from using it or familiarising ourselves with it, and had it proved worth the effort, and possible, we would long ago have placed ourselves in position to advocate it, as none can knowingly do who have not tried it. In designing any engineering work, proportioned structures can be produced by either scale; the working drawings can be then made to whatever system obtains in the shop of erection. This change from one or the other system in the drawing room is a matter of no difficulty whatever. The change from one system to the other in the workshop, however, involves more than the usual advocates conceive of.

To show the measure of the misapprehensions, as regards its effect on the engineering profession, on the part of the enthusiastic advocates of the exclusive metric system, I will pass by some lesser lights and seek illumination from the central luminary.

Professor Frederick A. P. Barnard, S.T.D., LL.D., who was President of the American Metric Bureau, and of the American Metrological Society, said, in December, 1877:—" It is now little more than a dozen years since the movement in favour of the reform of the confused metrological system of the United States was set on foot. Originating with a few '*advanced thinkers*' (the italics are mine) and regarded with indifference by the multitude, it encountered, as it is the fate of all efforts to emancipate mankind from the burden of traditional evils, to encounter a much larger degree of opposition than of encouragement." Then, after denouncing many of those who oppose the forced introduction of the system, he says:—

" Among the arguments urged by those who maintain the impossibility of change only one appears to have much force, and that is the argument drawn from the dependency of machinery upon minute exactness in the measurements of parts, and from the great expense which would attend the adaptation of machine shops and machines to a new system." Quoting the majority report of the Franklin Institute as to probable cost, and referring to the second report of the committee of the New York Uni-

versity Convocation, in which report the number of dimensions requiring separate indications on the drawings of a 25-horse-power steam engine are given, he continues:—" Singularly enough these statements, and all the rest of the same class in both the reports referred to, instead of being arguments against the abolition of the present metrological system and the substitution of the metric for it, afford the strongest reason for believing that that is precisely the thing which ought to be done. We desire, I suppose, to create a demand for our steam engines and our manufacturing machinery on the continent of Europe. * * * But a steam engine or a machine, all of whose parts are measured in English linear measures, if transferred to a metric country and there, by accident, disabled, becomes nearly useless, *since the shops of such a country afford no facilities for repairing it*," etc. (the italics, again, are my own).

It seems needless to tell engineers that these statements show so entire an ignorance on the part of Prof. Barnard of the merits of the case as can scarce be credited from such a source. I feel ashamed to tender to him an explanation of what is involved.

The unit of measurement used in making a machine does not in any way complicate the repairs of that machine. Machines built in Great Britain do not always agree with any of the even sizes in the United States; yet this discrepancy is a matter of no moment in the repairs of any of them. If we fail to find sizes corresponding to American sizes in British machines, presumably built on the same scale of linear measurement as the American ones, neither do we find even millimeter sizes, always, in machines from France or Germany.

In the injector department of Messrs. William Sellers & Co., Inc., of Philadelphia, the metric system has been employed for many years as fully as the system can possibly be applied to machine shop work, and to all intents and purposes as completely as it is used in France and Germany, and this was done some years before Professor Barnard's " few advanced thinkers " undertook their task of metrological reform. During all this time and for many years previous to the adoption of the system we have taken pains to inform ourselves, so far as lay in our power, as to the possible good to be derived from the system in the drawing room as well as in the shop. We inquired into its defects, and endeavoured to overcome them by the same means as are resorted to in metric-using countries. In this department of the shops the product is scaled to metric sizes and designated by metric names. Small tools and gauges are made from drawings figured in millimeters in every part except where screws and screw threads are required. Screws to be cut on existing lathes cannot be conveniently figured metrically, unless we adopt the custom of some German shops to figure in one dimension and make gauges to some other one. A screw bolt in Germany called 25 mm. diameter must be made 25.4 mm. size to conform to the screw system in use there; it will have 8 threads per inch and consequently 8 threads per diameter (I will explain this later). Screws cannot be metrically divided, until metrically divided lead screws have been originated and put in the place of the inch-divided lead screws common to all lathes in all parts of the world.

The people into whose hands the Sellers injectors pass know nothing of the scale of proportions to which they have been made. If some piece needs repairs and its shape has been lost by wear, it is needless to say that a knowledge of the scale would give no clue to that shape, but from some existing original any part can be copied; to copy requires no knowledge of the scale used. Repairs, too, as a rule, require deviation from original size to compensate for wear.

While the value of the unit of measurement may be of little moment in repairs, it is, however, all-important in the first production of machines. This leads me to another misunderstanding on the part of those whom Prof. Barnard classes, I presume, with his advanced thinkers; this cleared away, will

bring us to the position required in a judicious consideration of the two systems in their application to the machine industries. I quote now from a pamphlet by Dr. Persifor Frazer.

This pamphlet, says one of the Metric Bureau tracts, " contains more points, all well made, than any other of the same size on the subject." One of " the points " was suggested to him by reading a manuscript paper on the subject, said to have been written by an American engineer. The point made is this:—" Lengths, breadths, thicknesses, capacities, and weights of things are related to the accomplishment of man's purposes and are varied to conformity with the inflexible laws of mechanics for different motors, strains, and materials; no change of system will alter in the least their dimensions, though it may give them different names. * * * The grand truth of mechanics is, that the properties or dimensions of parts of machinery to accomplish any given purpose will be unaffected by any standard of length or weight applied to the part." This is a very good point, sounds well, but as the facts are not exactly as stated, the point is a dull one. No workshop in the land is or can be equipped with minor tools and gauges for the production of all sizes by infinite gradations. The calculated proportions of machines, the sizes indicated by " the inflexible laws of mechanics," are sizes which must be made to conform to the nearest existing means of production and the merchantable sizes of the matter to be worked into shape.

In shop practice and in mercantile practice, to avoid an endless variety and confusion of sizes, certain dimensions in progressive order are adopted, being the sizes found most useful and salable. These progressive sizes we may call, in order to make the matter easily understood by " advanced thinkers," shop sizes and merchant sizes.

It is by the use of well-considered ranges of shop and merchant sizes that the maximum of convenience is obtained at the minimum of cost. Hence one metrological system may be found to possess advantages over another when put to the test of practice. The one that is best in affording the most convenient and the most easily used and memorised series of sizes should not be called unphilosophical.

The resting-place for memory in the American series of shop sizes is the inch. The inch is subdivided by a process of repeated halving down to $\frac{1}{16}$ in the usual grade of shop and merchant sizes, as in bar iron. This gives 16 sizes to the inch for small sizes; 8, 4, 2 or 1 to the larger sizes. If a machinist should order from us a set of caliper gauges from $\frac{1}{8}$ up to 2, advancing by $\frac{1}{16}$, and from 2 up to 4, advancing by $\frac{1}{8}$, we are at once informed of the shop system contemplated in his workshop.

Calculations based on the " inflexible law of mechanics," as read by finite man, intimate for the size of a certain part of some machine a dimension of 3.95 inches diameter, but the prudent engineer has possibly assumed a sufficiently ample factor of safety to permit him to select $3\frac{15}{16}$ inches, the nearest shop size below the theoretical size, $3\frac{15}{16}=3.9375$ inches. He desires to use this shop size, because 4-inch iron, an obtainable merchant size of bar iron, will clean up from the black to this size; but if his dimension relates to castings or forgings he may select 4 inches as a shade stronger.

Metric-using people have ranges of shop and merchant sizes, too; when I come to compare their possible series and their actual series with our own, some faint glimmer may come to those who now know nothing about the matter of the fact that our unphilosophic system is not so very bad, after all.

In regard to what is involved in each shop size, in a money point of view, I will give but one single example. The inquiry to the tool-room keepers of Messrs. Sellers for a list of the separate devices used in producing one size, viz., $1\frac{1}{4}$-inch, brings to me the names of 129 articles or sets of articles, such as drills, reamers, gauges, boring bars and cutters, taps of all kinds for all sorts of uses, hardened mandrels, etc., etc. These many pieces, costing a very appreciable

sum, represent one size only. They tally with, and belong to, the dimension marked $1\frac{1}{4}$ in many thousand places on drawings, which have been accumulating for years, to patterns loading down our pattern lofts, to gear wheels interchangeable over a continent, and to the output of our factory for years. So important in an economical point of view has come to be this shop-size series that machines built in one shop, if it be reproduced (not repaired) in another, must be redrawn to conformity to the shop system in use before the work can be begun to advantage. Year by year this harmony in shop sizes in America spreads over a larger area. Entire harmony in essential points exists in many of the leading shops. There are, however, examples still to be found in which machines built in one shop have no dimensions in common with the shop sizes we use, as compared to our inch series or our millimeter series, for we use both. The expert recognises such machines as having been built to gauges varied by the judgment of the master workman, or by the more costly method of fitting one piece to another already completed, a process not admissible in any well-regulated machine shop.

A good workman may, by hand, construct, we will instance, a sewing machine. He will alter and try, and rearrange its parts until he has satisfied himself with the result. He may not have scaled this machine to any system. It goes to the manufacturer, who must perforce change some of the wild-cat sizes to conform to merchant sizes of the material to be used. For the rest, he may be content to fit gauges and templates to the model and reproduce it in minute exactness. We recognise, however, in every well-arranged series of shop sizes, and in the means employed to maintain size, the highest value of possible merchantable good workmanship, for in such possibilities we recognise economy in tools as well as in work, in interest on capital and in wages. This system has been growing year by year in spite of our so-called unphilosophical metrology. Eli Whitney, in 1798, gave a lesson in this direction, when he began to make muskets with interchangeable parts in Springfield, Massachusetts; but it was not until 1855 that the British Government recognised what Whitney had done, by importing American gun-making machinery. Since Whitney's time the standard system has been carried into all branches, not only of our own trade, but into all the requirements of other trades as well.

The metrology of the American shops is based on the inch, and on it only. This dimension is cut up into minor parts by halving to any degree of subdivision, practically in shop sizes to $\frac{1}{16}$; it is also divided into 10 parts and into 12 parts when such divisions serve any good end. All such divisions have their uses and lead to no confusion. The inch squared is the base of our strains and pressures. The inch cubed gives us capacities. Later, I will speak of 12 and 36 inches squared and cubed. This one unit, the inch and pound weight of 7000 grains Troy, is all that a machinist needs to carry on his business. His inch is the same inch as is used in Great Britain and in the Russian machine shops. His pound is the pound in common use in Great Britain.

In America we have dropped some needless weights and measures. We do not use in the machine shop the ton of 2240 pounds nor its quarter or its hundred weight; we do use a weight called "ton of 2000 pounds." This is the factor weight in strains, and by it we sell machinery. Other trades may retain some of these useless things; I am speaking only of machine-shop practice.

The unit of measurement in France and in Germany is the millimeter. It is not and cannot be the meter for the following reason:—The great majority of all sizes used in the construction of any machine, whether it be big or little, are less than one meter. By the use of the millimeter only, decimals are avoided. Eight millimeters must be written 8 in the millimeter scale, while it must be written 0.008 in the metric scale. This is reason enough; for by the use of millimeters, only, confusion

of signs is avoided, and the danger incident to decimals is avoided; hence all drawings are figured in millimeters only, up to dimensions measuring many thousand millimeters. This little dimension is then squared and cubed, or, ten or one hundred millimeters are squared and cubed, for the uses corresponding to the squared and cubed inch and foot. As may be expected, happy coincidences of conveniences are found in either system. Thus, an ardent metric advocate instances that 1 kilo to the square centimeter is just one atmosphere. We say 15 pounds to the inch is an atmosphere. Neither one is right, but the 15 pounds to the inch is 1 per cent. nearer right than the other is. For a machinist who seldom uses atmospheres a happy coincidence on the other side will be of more service. It so happens that wrought iron bars with parallel sides measure in square inches of this section just one-tenth of their weight in pounds per yard. Now, inasmuch as "shapes" in iron are rated by the pounds per yard, for convenience in large structures, so it comes to pass that when we know the weight per yard of any wrought iron "shape," we know at once its sectional area. Inasmuch as compression and extension and factors of safety are involved in a knowledge of cross-section, it is handy to be able to find it so readily,—is it not? A shape iron, 80 pounds to the yard, has 8 square inches area of section. If it is good for 10,000 per square inch in extension we may load it with 80,000 pounds.

I have set out to compare the two scales,—to compare the two units, rather, after an experience of many years with both. The inch is 25.4 times larger than the millimeter. These are the two dimensions we are to compare.

We will begin in the drawing room. Here "the inflexible laws of mechanics" find their first expression in form on paper. Few machines, or even parts of machines, can be drawn full size. Hence comes the need of "scales." There is reason in all things, even in scales. The unwritten law of most machine shops is to make every drawing as large as possible, as near full size as the nature of the subject and the dimensions of the paper used will permit. We have in our drawing room about 125 drawers, each of which will take in, without folding, drawings 52 inches (1320 mm.) long by 33 inches (840 mm.) wide. This is about as large a sheet as we can use to advantage, and tracings from these are not unmanageable in the workshop.

For metrical drawings we can use the following scales only:—

Full size in which 1 mm.=1 mm.
One-half size in which ½ mm.=1 mm.
One-fifth size in which 2 mm.=1 cm or 2 cm.=1 dm.
One-tenth size in which 1 mm.=1 cm. or 1 cm.=1 dm.
One-twentieth size in which 5 mm.=1 dm.
One twenty-fifth size in which 4 mm.=1 dm.
One-fiftieth size in which 2 mm.=1 dm.

Down to the one-tenth scale the dimensions can be read from a good millimeter rule; for the one-twentieth, the one-twenty-fifth and the one-fiftieth scales must be constructed. The jump from one-half to one-fifth size is unfortunate. Could we conveniently quarter the whole size we would have an increased area section, a matter of much moment. One-fifth of 10 inches is 2 inches, and the square of 2 is four. One-fourth of 10 inches is 2½ and its square is 6¼, a gain in size of over 50 per cent.; a gain in comfort, in convenience, and in eye-sight. Here we catch the first glimpse of the advantage of our own system; for with it a draughtsman can, from an ordinary well-divided inch rule, obtain the following scales:—Full, ½, ⅓, ¼, ⅙, ⅛, $\frac{1}{12}$, $\frac{1}{16}$, $\frac{1}{24}$, $\frac{1}{32}$, $\frac{1}{48}$, $\frac{1}{64}$, —12 gradations, as compared to 7, and to these 12 can be added with perfect ease 5 of the others, making 17 in all, if the preference be for the decimally-divided inch, a scale carried in the tool box of every machinist, and obtainable from the two-foot rule in so common use.

The scale series in most common use is that of ½, ¼, and ⅛; this halves down from whole size and can be raised, in rapid drawing, by taking off diameter sizes from one drawing and using them as radius dimensions in the other, a process impossible between ½ and $\frac{1}{5}$ sizes.

The true value of this extended series

of scales, with its peculiar advantages, is manifest to any one familiar with both, and admits of no dispute. Is it a wonder that draughtsmen brought up under a metric rule take so kindly, as they do, to our unphilosophical system?

Drawing is but a small part of the engineer's work. More or less calculating has to be done; many hours must be spent in figuring strains, estimating weights, determining speeds and what not. This brings us to the test of convenience in calculation, to the stronghold of the metric advocates. It is just here that Dr. Edward Wigglesworth, in his metric tracts, comes out the strongest in his peculiar style. He says that Americans, self-ruling, are really too lazy, while merely claiming to be too stupid, to use the system. He says, "Shame on a country which to party gives up what was meant for mankind." It is claimed that the decimal notation of the metric rule gives greater facility in calculating, but that this is not its sole advantage.

Mr. Frazer says:—"Let the carpenter or mason be asked how many tons of water a structure, whose external (he probably means internal) dimensions are given, by his rule, will contain, and they will acknowledge that the decimal division is not the only advantage of the metric system, but that another is the perfect relation of extension, capacity and weight." For a structure 5 feet square and 10 feet deep the carpenter would divide, in his head, 250 by 32 and say 8 tons, nearly, or 7.8125 tons exact of the tons of 2000 pounds in use, in all such measurements. The metric system would give for a nearly similar structure, say, $1.5 \times 1.5 \times 3$ meters, a result obtained by tedious multiplying only; but what then? This problem applies to water only. If these spaces were to be loaded with bricks the metric multiplication must be still further multiplied by the specific gravity of bricks, thus:—$1.5 \times 1.5 \times 3 \times 1870 = 12{,}662.5$ kilos, while our mason's sum would read $5 \times 5 \times 10 \times 125 = 31{,}250$ pounds of common hard bricks, with an ease of calculation rather in favor of the two-foot rule.

I have mentioned the innumerable books which have been prepared, simplifying processes of calculations by tabulating the results of experiments on the basis of the inch unit. Of these books the British experiments form a large bulk of the valuable engineering knowledge of the world. Hodgkinson, for example, experimented with the crushing resistances of various substances, and the result of his experiments are in the possession of all engineers. He took samples in cylindrical form, 1 inch diameter, 2 inches long each, for these experiments. Armengaud quotes these experiments and tabulates the results, saying they were obtained by Hodgkinson, *avec des cylindres de* 0 ^{m}0254 *de d^{tre} sur* 0808 m. *de haut*" $=''1 \times 2''$, and from these he deduces, for example, that ash has a crushing resistance of from 610 to 653 kilos per square centimeter.

Mr. Trautwine, quoting Eaton Hodgkinson's experiments, also tells us that ash, weighing from 45 to 53 pounds per cubic foot, has a crushing value of 8600 pounds per square inch. Now, 1 pound per square inch $= .073077$ kilo per square cm., or 1 kilo per square cm. $= 14.2232$ pounds per square inch, $\frac{8600 \text{ pounds}}{14.22} =$ about 605 kilos to the square cm. Here, from Trautwine's deduction, the metric-using engineer will employ 605 as a factor where we use 8600 in the same case. He, because his unit of measurement is less, or, rather, requires more figures to express it, multiplies these many figures by a lesser factor, while we, expressing our dimensions with lesser figures, use with these figures a larger factor. In other words, we can complete our calculation sooner because we are able to deal with the largest measures compatible with convenience. We can use the cubic inch, the cubic foot or the cubic yard, at our pleasure, just as the mechanic selects his tools in accordance with the extent of his work, and does not waste time driving at a railroad spike with a tack hammer.

I have before me, as I write, French books and German books on mechanical

engineering. In some, both French and German, all or nearly all, formulas for strains are expressed in kilos per square cm., while Prof. Reuleaux, in his many valuable books of reference, seems to adhere to kilos per square millimeter. Now, to test the matter of convenience, in a way familiar to all mechanical engineers, let us go to Reuleaux for our information as to the strength of cast iron, in the familiar equation for beams of $W = \frac{4\,s\,b\,h^2}{6\,l}$. Reuleaux says the value of s may be taken as 4 kilos per square mm.; this equals 400 kilos per square cm., or 5689 pounds per square inch. Let our example be a cast iron beam of rectangular section, 9 inches deep, 4 inches wide, and 10 feet between its supports. Given, to find its safe load in the middle:—Let us round up these dimensions into a somewhat similar beam, measured in mm., $230 \times 100 \times 3000$. Now, $h = 230$ or 9, $b = 100$ or 4, $L = 3000$ or 120. The formula then reads

$\frac{4 \times 4^{k} \times 100 \times 230 \times 230}{6 \times 3000} = 470^{2k}$ for all dimensions, in mm.

or

$\frac{4 \times 400^{k} \times 10 \times 23 \times 23}{6 \times 300}$ for all dimensions, in cm.

If we take 6 from the denominator, then

$$\frac{4 \times 66.6 \times 10 \times 23 \times 23}{300}.$$

If we make the formula good for cast iron only, and use centimeters in the numerator and meters in the denominator, which is the best we can do,

$\frac{2.664\,b\,h^2}{l}$ for cast iron

$$= \frac{2.664 \times 10 \times 23 \times 23}{3}.$$

Compare this with $\frac{4 \times 5689 \times b\,h^2}{6l}$

which reduces to $\frac{316\,b\,h^2}{l}$ for cast iron,

and reads $\frac{316 \times 4 \times 9 \times 9}{10}$.

My note-books are full of such examples as this; it has been my wish to test this matter thoroughly; my experience covers many examples of engineers and draughtsmen educated in metric-using countries, who, when they come to us, learn to use our measures as quickly as we can learn to use theirs, but adopt our methods of calculation as involving fewer figures. Thus, for all practical purposes, in strains, what will be strong enough in kilos, if we assume two pounds to the kilo, will be near enough right, and if the "grand truth of mechanics is that properties or dimensions of parts of machinery to accomplish any given purpose will be unaffected by any standard of length or weight applied to the part," then it is possible to arrive at the theoretical proportion by either system, and it is presumable that the workmen will select the easiest one to work with, the more so if the easiest one happens to be the one he has been most used to. I have yet to see the example of a metric-educated draughtsman working in millimeter calculations on an inch measured machine, while with our own experience with both we could follow him in either.

Cubic inches go farther than cubic millimeters, *i. e.*, they involve few figures in their expression; because a cubic inch is 16,000 times larger than a cubic millimeter, it is 16 times larger than the cubic inch, yet is the cubic foot 27 times larger than the liter, and between the liter and the cubic meter there is no unit of measurement.

The harmonious relation of extension, bulk, weight, and all that, comes out strongest when we deal with distilled water. Away from that precious fluid, and we are required to know and use the weights of matter as they relate to water. I must confess I see no difference in favour of hunting up in books the specific gravity of matter, or in looking for the weight of matter in pounds per cubic inch, or foot, or yard.

With distilled water engineers have little to do; when they note the solid matter accumulating in their boilers, they wish they had more to do with it. In hydraulic calculations the weight of distilled water, however, may be near enough to the weight of the water they

have to deal with to enable them to reap all the advantages desirable from the system, did not the small units, the millimeters, or the many figures in the decimals of the meter, mar the result in a labour-saving point of view.

The value of the drawing room system is tested or tried when the drawings reach the machine shop. It is there that errors are found out. An incorrectly figured drawing costs nothing on account of the errors so long as that drawing rests quietly in its drawer; but it costs fearfully when the error is discovered in the partially finished machine. All engineers agree on one thing, viz., the fewest possible figures that can be used to express dimensions clearly, the easier it is to work to the drawing, and the less liability to make mistakes. Beautiful as is a decimal system in calculation, and we all use it, save in mental arithmetic, it has been found advisable to avoid the use of decimals as far as possible on the drawings used in workshops, even in metric-using countries. A misplaced point is an easy error to make, and may cause no end of trouble and expense.

I had hoped for gain in the drawing room from the use of metric scales; I expected to find more than in the machine shop; I have been disappointed in both. In the machine shop we come to test the value of shop sizes and merchant sizes, or rather the series possible in both, with one or the other system. For what is in use abroad, we look to Germany rather than to France for information useful to us, inasmuch as in Germany the metric system was taken up at a late day, and was introduced in its entirety without shock. To united Germany anything was better than their frightful confusion of fifteen inches in use, all differing from the inch still used with their screw threads, and differing from the inch of Great Britain. The metric system is incomparably better than their previous entire want of any uniformity. With us the matter is very different, as will be seen more clearly as we advance. We divide our unit, in practice, into just what parts are best suited to express our practical wants, and the system in our machine shops is uniform over a continent.

The first item of manufactured matter entering the machine shop door is bar iron. The merchant sizes of round, square, etc., in America, are by $\frac{1}{16}$, by $\frac{1}{8}$, by $\frac{1}{4}$, etc. In Germany, similar bars advance in size by 1 mm. up to 40, by 2 mm. from 40 up to 80, and by 5 mm. above 80. This system may be memorised by 40 and 80—by 1, 2 and 5. It is the best that can be done with a system tied up to an unhalvable scale. It does not agree with the British or American sizes except in a few sizes. The system of bolts, diameters and threads per inch, common or general over the continent of Europe, is that known as the Whitworth system. They still adhere to this system, as they do to the British system of gas and steam pipes and their fittings. The Whitworth system pitches its threads to even numbers or half numbers per inch in length. These pitches are easily obtained from the lead screws of all lathes, which are 2, 4 or 6 threads per inch, as a rule. Having given up the inch, the Germans formulate their threads per diameter (see tables at the end of this paper). For the names of the bolts, they must either retain their English names, and call a 25.4 mm. bolt one inch, or they must call it what it is, 25.4 mm.; but some call it 25 mm., and make it .4 mm. larger. This inch bolt has 8 threads per inch, and, as the diameter, too, is 1 inch, it can be said to have 8 threads per diameter.

A $1\frac{1}{8}$-inch bolt measures 28.6 mm.; it may be called 29 mm. size; it must be cut out of 29 mm. iron, the nearest merchant size, with a loss of $\frac{4}{10}$ of a millimeter. This loss does not seem much, but the dies which have to cut it off tell the story very soon. The Whitworth scale gives the same pitch to $1\frac{1}{8}$ and $1\frac{1}{4}$ screws, viz., 7 per inch. The exclusive metric shops call the one $7\frac{7}{8}$ threads per diameter, and the other $8\frac{3}{4}$, and yet they are practically the same and must be cut with the same combination of change wheels on the lathe. Here is a precious example of what comes from trying to harmonise two

systems under one nomenclature. The screw system in general use is so good, it has been so long in use, its disturbance would shock so many interests, that it is unwise to give it up, as unwise as it would be to adopt the American gas-pipe system in place of the British, or for Americans, for the sake of uniformity with Great Britain and Germany, to attempt to force the adoption of their system into American houses.

America has, for the last half century, been striving in its own way towards equalisation of its standard sizes. The immense railroad industries demand this. Standard wheels on standard axles,—standard fit sizes for both,—are all founded on an inch scale of sizes.

Standard shafting for mill gearing gives a good example. It has been demonstrated that bars, carefully rolled to size in rounds, can be reduced to turned shafting with a loss of 1½ mm., or $\frac{1}{16}$ inch to the diameter. Hence, bars 2, 2¼, 2½, 2¾ 3 inches, etc., are made into shafts $\frac{1}{16}$ less in diameter, sold by their full-size, names, *i. e.*, by the name of the iron from which they have been made and designated by the affix "shafting size." A 2-inch shafting size bar measures 1 15-16 inch, and a pulley ordered to-day with an eye to fit a 2½ or a 4-inch shaft made thirty years ago will be found to be to size. Now this American shafting sells freely in Europe and no one complains of its size. He can command the markets of the world who can make the best machinery at the least cost, and that machinery will be taken and used and no questions asked about its inches or its millimeters.

A scale of shafting sizes so uniform and so easily expressed by ¼ up to 3½ and by ½ inches to sizes above 3, is met in metric countries by the ease of an advance by 5 mm. only. To obtain the economy of American shops their shafting sizes should be 1½ mm. less than their name, *i. e.*, a 100 mm. shaft should be made 98½ mm. diameter, but the Germans have seen fit to retain even sizes and thus are obliged to use 57 mm. iron to make a 55 mm. shaft, and 92 mm. iron to make a 90 mm. shaft, while on still larger shafts they must be content to lose 5 mm. at each turning.

The shop sizes in America harmonise with the merchant sizes and with convenience. We cannot change them. It would be unwise, I think, to do so in face of the obtainable metric sizes, if we could. One other example of good and bad systems, and I have done with this part of the subject.

An essential of all machine shops is a drill system; a series advancing by 1 16 up to 1 inch, and by ⅛ inch up to 2 inches, is equivalent to an advance by 1½ mm. in a metric series. Such an advance as 1½ mm. is impracticable, because it must be memorise l entire; it affords no holding place for the memory. Twist drills were first made in America; they were so good, so useful, that American drills came to be the rage in Europe. After a time good makers there began their manufacture. I will mention one house, founded in 1834, that of Heilmann, Ducommunn & Steinlen, at Mulhouse, Alsace, one of the best known houses in all Europe. They make twist drills from 10 mm. up to 50 mm., advancing by 1 mm., but their price list tells us that the sizes marked in bold face type are the sizes in use in their own shop. These sizes are:—10, 12, 15, 18, 20, 23, 25, 28, 30, 32, 35, 37, 40, 42, 45, 47, 50. Here a series of sizes approximating the British ones is adopted, but it is a series which must be memorised entire, as its advance is not by two or by three, either, in regular sequence. We cannot question the wisdom of the men who have selected these shop sizes to meet their known wants; they rank too high as workmen, they know too much to challenge criticism. Doubtless, this scale of sizes is about the best they can do with the metric system; we would not tie ourselves to it.

I could continue the list of practical difficulties until I had filled a volume. They run through the entire list of all that goes to make up the requirements of our profession, and show how unwise we would be to change, if we could do so, for the sake of harmony with Europe.

We have not adopted the Whitworth system of screws in America, and yet, by so doing, we would place ourselves in harmony with all Europe. We recognise objections to the system, and when those objections were clearly pointed out by Mr. William Sellers, and he proposed a system free from the objections, his system was accepted by the committee of the Franklin Institute, and then by many departments of the United States Government. Had the metric system shown itself to be the perfect system it is claimed to be, it, too, would have been taken up more generally at a time when it was easier to have done so than now.

The American mind is quick to note what is to the advantage of American mechanics. We take up quickly what is good to hold to, and we will not accept what we have demonstrated to be less useful. This was made manifest to Prof. Reuleaux, director of the Industrial Academy, Berlin, and was expressed by him in his report on motors and machines at the Paris Exposition of 1867. In commenting on the many novelties from America, he says:—"Upon the whole, it may be said that in machine industry Great Britain has partly lost her formerly undisputed leadership, or that she is about to lose it. The healthy young transatlantic industry, which continually withdraws from us energetic and intelligent heads and robust hands, makes, with the aid of her peculiar genius, the most sweeping progress, so that we shall soon have to turn our front from Great Britain westward."

Then, in commenting on the rapidity with which American ideas were finding a home in Germany, and the genius for inventions of this kind as peculiar to Americans, he says:—"They are distinguished from us by more direct and rapid conception. The American aims straightway for the needed construction, using means that appear to him the simplest and most effective, whether new or old. * * * The American really constructs in accordance with the severest theoretical abstractions, observing, on the one side, a distinctly marked out aim, weighing on the other the available means or creating new ones, and then proceeding, regardless of precedents, as straight as possible for the object. * * * This spirit is strikingly prominent in the (Wm. Sellers) system of screw threads which he has boldly placed alongside of the old, venerated Whitworth system, in spite of the terror of its numerous adherents, after he had discovered actual deficiencies. A proper valuation of this proceeding contains the most instructive hints for our higher technical institutions."

There is an irreconcilable discord between the inch and the divisions of the meter. I was a signer of the majority report of the Franklin Institute which opposed the compulsory adoption of the metric system. That report was prepared and written by the chairman, the late Mr. Wm. P. Tatham, afterwards made president of the body which adopted it, as their view of the matter. Mr. Tatham was a man of culture and a hard student. His business as maker of lead pipes would have been less affected than that of almost any other manufacturer by the introduction of the metric system. He said, and I subscribed to the statement, that he believed that the ultimate benefits of the change proposed would be of less value than the damages during the transition. This was on the suppositious view that ultimately some would be benefited. As an engineer, I can see no possible good to come to British American machinists from the change. Its introduction exclusively would not diminish his labour in any way; it would not cheapen his product; it would increase its cost. It is, in fact, however, so impossible, in view of existing matters and existing harmony in interchangeable matter, that should the metric standard be made the only legal standard to be used in buying and selling, the engineering establishments now in existence could not heed the law, but must, perforce, use their existing tools and gauges of precision, and continue to make material in conformity with existing matter.

The metric system was admitted in

WHITWORTH'S SCREWS.
In use in the United Kingdom and Europe, especially in Germany.

Diameter.—English Inch.	Diameter.—Prussian Inch.	Diameter.—Millimeter.	Diameter at Root of Thread. English Inch.	Number of Threads per Diameter.	Number of Threads per Inch.—English.
¼	0.243	6.4	0.186	5	20
5-16	0.303	7.9	0.241	5⅝	18
⅜	0.364	9.5	0.295	6	16
7-16	0.425	11.1	0.346	6⅛	14
½	0.486	12.7	0.393	6	12
⅝	0.607	15.9	0.509	6⅞	11
¾	0.728	19.0	0.622	7½	10
⅞	0.850	22.2	0.733	7⅞	9
1	0.971	25.4	0.840	8	8
1⅛	1.092	28.6	0.942	7⅞	7
1¼	1.214	31.7	1.067	8¾	7
1⅜	1.335	34.9	1.162	8¼	6
1½	1.457	38.1	1.287	9	6
1⅝	1.578	41.3	1.369	8⅛	5
1¾	1.700	44.4	1.494	8¾	5
1⅞	1.821	47.6	1.591	8 7-16	4½
2	1.942	50.8	1.716	9	4½
2¼	2.185	57.1	1.930	9	4
2½	2.428	63.5	2.180	10	4
2¾	2.671	69.8	2.384	9⅝	3½
3	2.913	76.2	2.634	10½	3½
3¼	3.156	82.5	2.857	10 9-16	3¼
3½	3.399	88.9	3.107	11⅜	3¼
3¾	3.642	95.2	3.323	11¼	3
4	3.885	101.6	3.573	12	3
4¼	4.127	107.9	3.805	12 7-32	2⅞
4½	4.370	114.3	4.055	12 15-16	2⅞
4¾	4.613	120.6	4.285	13 1-16	2¾
5	4.856	127.0	4.535	13¾	2¾
5¼	5.098	133.3	4.790	13 25-32	2⅝
5½	5.341	139.7	5.020	14 7-16	2⅝
5¾	5.584	146.0	5.238	14⅜	2½
6	5.827	152.4	5.488	15	2½

TABLE OF SCREWS.—By Reuleaux.

Diameter of Screw. d=mm.	Diameter at Root of Thread. d=mm.	Threads per 10 mm.	Thickness of Head. Millimeters.	WHITWORTH'S. Diameter of Screws d=Eng. in.	Threads per 1 in. Eng.	Threads per Length=Diam.
6	4.1	7	7	¼	20	5
8	5.9	6	8	5-16	18	5⅝
10	7 7	5½	10	⅜	16	6
12	9.5	5	11	½	12	6
15	12.2	4½	13	⅝	11	6⅞
18	14 9	4	15	¾	10	7½
21	17.6	3¾	17	⅞	9	7⅞
24	20.3	3	20	1	8	8
27	23.0	3	22	1⅛	7	7⅞
30	25.7	2½	24	1¼	7	8¾
34	29.3	2½	27	1⅜	6	8¼
38	32.9	2½	29	1½	6	9
42	36.5	2⅛	32	1⅝	5	8⅛
46	40.1	2⅛	35	1¾	5	8¾
50	43.1	1⅞	38	1⅞	4½	8 7-16
55	48.2	1⅞	41	2	4½	9
60	52.7	1⅝	45	2¼	4	9
65	57.2	1⅝	48	2½	4	10
70	61.7	1⅜	52	2¾	3½	9⅝
75	66.2	1⅜	55	3	3½	10½

the United States to an equal footing, in point of law, in 1866. It had not been legalised in any way when we, Messrs. Sellers & Co., for good reasons, introduced it into our own workshop in Philadelphia, and yet, at that time, we asked no one's permission to do what we pleased in the metrological management of our own business. We had a chance to try the system in making something which did not clash with existing merchant sizes; once having perfected an organisation in this department we became fixed in its continuance. Precisely the same reasons why we cannot change our general system into the metric hold against our giving up the metric system in the departments where it is in use.

If the change to the metric system will aid commerce, let the merchants do as we have done,—try it. Commerce depends, in a large measure, on the possible output of our workshops. The engineer controlling the workshop, and who, to be successful, must be a merchant, too, knows too well how he stands to give up a practically useful system, more convenient to him after having tried both, for the sake of any fancied conformity with other countries. He can give up no vantage ground. His success in his life-battle in these days of active competition depends upon wise economies to enable him to prosper.

I am tempted to touch on the educational view of the subject, but will content myself with very few words. When engineers are told that the change to the metric system would save two years, or one year, in the school life of every child, they ask how many years are now devoted to mathematics only, in the average four years' schooling of the mass of our boys, and ask, what is to be lopped off to make this saving? Many a good workman who has risen to a high rank among educated mechanical engineers had too few years at school to admit of a month's saving in any one branch of his studies.

It is the thing just now to favour the change. A young engineer enlisting himself in the ranks of the metrical reformers (?) buys a cheap scientific notoriety. He is brought into sympathy with the self-constituted advanced thinkers. Those who oppose the change, after having become familiar with both,

TABLE OF AMERICAN AND BRITISH GAS PIPES.

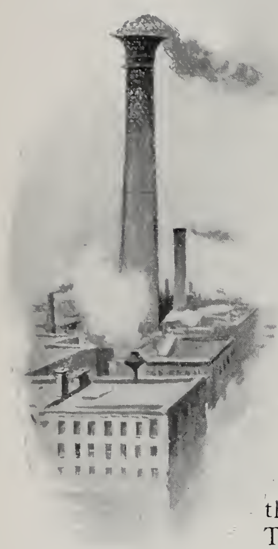
Nominal Diameter.	Act'l outs. Diam. in Engl. Inch.	No. of Threads per Inch.	Act'l outs. Diam. in Engl. Inch.	Act'l outs. Diam. in mm.	No. of Threads per Inch.
	U. S. Standard.		British Standard.		
1/8	0.405	27	0.406	10.318	19
1/4	0.54	18	0.531	13.493	19
3/8	0.675	18	0.625	15.875	19
1/2	0.84	14	0.812	20.637	14
5/8	----	--	0.906	23.018	14
3/4	1 05	14	1.031	26.194	14
7/8	----	--	1.187	30.162	11
1	1.315	11½	1.312	33.337	11
1¼	1 66	11½	1.625	41.274	11
1½	1.9	11½	1.875	47.624	11
1¾	----	--	2.125	53.974	11
2	2.375	11½	2.375	60.325	11
2¼	----	--	2.625	66.674	11
2½	2.875	8	3.0	76.199	11
2¾	----	--	3.125	79.374	11
3	3.5	8	3.5	88.898	11
3½	4.0	8	3.937	100.01	11
4	4.5	8	4.437	112.71	11
4½	5.0	8	-----	------	--
5	5.563	8	-----	------	--
6	6.625	8	-----	------	--
7	7.625	8	-----	------	--
8	8.625	8	-----	------	--
9	9.688	8	-----	------	--
10	10.75	8	-----	------	--

are said to "sever themselves from the congenial sympathy of the enlightened public opinion of to-day." The mechanical engineer can accept nothing as true until he has demonstrated the truth by experiment; at least, in anything capable of being put to the test of experiment. It is in the power of any intelligent man to test the metric system as others have done. He will, I think, find that the savants who originated the scheme before mechanical engineering, as it now exists, was known as a profession, made the mistake of beginning at the wrong end, the big end of the scale, the size of the world; and by the time they had cut it up or down to human wants it came out less fitted to human requirements than if they had recognised in the beginning the needs of the beings who were to use it.

Our metrological reformers urge us to adopt a new system in place of our present one, a system that harmonises in no way with anything we now use. This new system is practically based on a certain measure over 39 inches long. This is cut up into 1000 parts, and 100 of these parts cubed give their primary vessel of measurement. The contents of this vessel in distilled water under certain conditions form their pound weight. Had the British yard of 36 inches been so treated it would have been as good a system, but no better. It would have been as inapplicable comfortably to our profession as is the metric. The wonderful extension of the metric system to time and infinite space was given up as impracticable long ago, and we are now asked to bear the shock of a mighty change to use this inconvenient system, this unhandy system of ten, for the sake of uniformity with some other peoples of the world.

THE ECONOMY OF ECONOMISERS

By Alton D. Adams



ONE pound of pure carbon, when completely burned, yields 14,500 heat units, or enough to raise 14,500 pounds of water one degree Fahrenheit in temperature. A fair grade of coal for use under steam boilers, yields about 12,000 heat units per pound, on perfect combustion, a part of this heat being due to some hydrogen compounds, in addition to the carbon, in the coal. The weight of the gases resulting from the burning of coal varies much, according to the relative amount of air admitted, but in the average boiler furnace fully 24 pounds of air are admitted per pound of coal burned, making the weight of the gases of combustion twenty-five times that of the coal consumed.

On leaving the boiler, the gases commonly range in temperature from 500 to 700 degrees Fahr., and 600 degrees may be taken as a fair average. Each degree of temperature through which the 25 pounds of gas are raised requires about 5.70 heat units, and for a rise to 600 degrees, the temperature of the outside air being 40 degrees, the gases for each pound of coal escape, therefore, with $(600—40)\ 5.7 = 3192$ heat units. Since the combustion of the coal, under favourable conditions, yields only about 12,000 heat units per pound, the heat escaping with the gases is $3192 \div 12{,}000 = 0.26$ of the total amount produced. Various other losses occur, in the way of conduction and radiation from boilers and furnaces, so that the efficiency of good steam boilers is usually from 60 to 70 per cent.

The true efficiency of a furnace and boiler is, of course, the ratio between the total heat contained in the fuel consumed and the heat transferred to the water and steam in the boiler. Starting with water at the pressure of the atmosphere and a temperature of 32 degrees Fahr., it requires 309.5 heat units to raise one pound of the water to a temperature of 337.8 degrees, at which the water must be at 100 pounds per square inch gauge pressure. To change one pound of water at this temperature and pressure into steam at the same pressure requires 875.5 heat units, which are called the latent heat of steam at 100 pounds gauge pressure. The sum of the heat units in the water and those required to change the water into steam, as just given, is $309.5 + 875.5 = 1185.0$, which is, therefore, the amount of heat necessary to transform one pound of water at 32 degrees Fahr. to steam at 100 pounds gauge pressure.

A ton of average coal, which develops about 12,000 heat units on perfect combustion, would change $12{,}000 \div 1185 = 11.2$ pounds of water at 32 degrees to steam of 100 pounds gauge pressure, if boilers had a perfect efficiency; but as the efficiency is frequently reduced to 75 per cent. by the loss of heat in the gases alone, and by other minor losses to about 65 per cent., the amount of cold water usually changed to steam at 100 pounds pressure is only about $11.2 \times .65 = 7.3$ pounds. If only low-pressure steam be desired, as for heating, the amount that can be evapourated per pound of coal is about the same,

since the total heat in steam rises but slowly with its pressure. Thus, at 5 pounds gauge pressure, the total heat of steam above water at 32 degrees is 1151 heat units per pound, instead of 1185 as above given for 100 pounds pressure. The losses of heat in the gases of combustion are practically the same, whatever the pressure at which steam is generated.

At the fire in boiler furnaces the temperatures usually range from 2500 to 3000 degrees, depending largely on the amount of air admitted. The gases reach the boiler tubes at a temperature of about 2000 degrees and are rapidly cooled in passing over or through them. In practice, it has been found undesirable to so extend the boiler surfaces or tubes that the temperature of the escaping gases is reduced much below 500 or 600 degrees, because as the surface grows larger and the tubes longer, the heat lost by radiation and conduction from the boiler increases and the internal circulation of the water is impeded. If the boiler surface is increased indefinitely, a point is soon reached where the losses due to radiation and conduction are greater than the gain in heat from the gases. This condition may be foreseen from the fact that the transfer of heat through the boiler plates and tubes varies approximately as the square of the difference in temperature between the water inside the boiler and the gases, while the heat losses from the boiler increase directly with its surface. As the gases are cooled, the transfer of heat from them to the water in the boiler goes on, therefore, much more slowly.

One of the most important means for the increase of boiler plant efficiency consists in heating the feed-water as much as possible before its entry to the boiler. But the practice of feed-water heating is very desirable apart from any considerations of efficiency, because of the internal strains imposed on a boiler when it is fed with cold water. The steam and a part of the water in a boiler at 100 pounds gauge pressure have a temperature of 337 degrees, and the introduction of cold water at 40 or 60 degrees gives rise to more or less severe strains on the tubes and plates through their contraction where the cold water comes in contact with the hot metal.

Exhaust steam from engines is much used to heat feed-water, and this practice is good as far as it goes, but results from it are quite limited for two reasons. In many large boiler plants the steam is used entirely, or nearly so, for heating purposes, and there is no waste exhaust. When non-condensing engines are used, and there is ample exhaust steam to heat feed-water, the temperature of the feed cannot be raised above 212 degrees Fahr. without creating back pressure in the engine cylinder, because water and steam can be heated only to 212 degrees in the open air. As a matter of practice, feed-water from heaters supplied with exhaust steam usually rises to little more than 200 degrees. Whatever advantage is obtained by the use of exhaust steam to heat the feed-water cannot be considered as an increase of boiler efficiency, and nothing is thus saved from the loss of about 25 per cent. of the heat energy from coal in the flue gases. Moreover, it is often the case that all of the exhaust steam can well be used for general heating purposes, if some other means are provided to heat the feed-water. It is also desirable to heat the feed to a higher temperature than is possible with the exhaust steam, as the hotter the feed-water, the less fuel must be expended in the boiler furnace to make steam.

While it is not desirable to reduce the temperature of the gases of combustion much below 500 or 600 degrees before they leave the boiler for the reasons above pointed out, it is entirely practical to take a large part of the escaping heat from these gases by passing them over other surfaces, and a vessel adapted to heat water by the waste boiler gases is, therefore, rightly called a fuel economiser. Such an apparatus may be used to advantage to heat feed-water, either alone or as a supplement to heaters that use exhaust steam. Most large power plants now operate with condensing engines, and feed-water from condensers usually reaches a temperature of as much as 100 degrees. Economisers, with

boiler gases delivered at 600 degrees, readily raise feed-water to 250 degrees, whatever the temperature at which it is delivered to them. The heat units required to raise one pound of water from 40 to 250 degrees are 211, and to raise one pound of water from 100 to 250 degrees 151 are necessary. To raise the temperature of feed-water to 250 degrees the temperature of the gases should not be reduced below about 300 degrees.

As shown above, the gases of combustion from one pound of coal, allowing for air dilution of 100 per cent., weigh 25 pounds and contain about 3192 heat units at a temperature of 600 degrees. The heat given up by these gases when reduced from 600 to 300 degrees in temperature amounts to $3192 \div 2 = 1596$ heat units per pound of coal burned. Allowing 12,000 heat units to be the total amount developed by the combustion of one pound of coal, the heat recovered from the gases under the conditions just named is $1596 \div 12{,}000 = 0.13$ of the whole. If boilers alone have an efficiency of 65 per cent., they transfer $12{,}000 \times 0.65 = 7800$ heat units to the water and steam for each pound of coal burned. The addition of economisers under the conditions named will give the combination an efficiency of $65 + 13 = 78$ per cent., and, if all of the heat extracted from the gases can be absorbed by the feed-water, the steaming capacity of the boilers will be increased by $1596 \div 7800 = 0.20$.

If feed-water goes to the economisers at the temperature it has in the open air, all the heat that is extracted from the gases will usually be required by it; but if the feed is first heated by exhaust steam, either at open-air pressure or in a condenser, it may well be that the additional heat it will absorb in an economiser will be less than can be recovered from the gases. Allowing that nine pounds of water can be evapourated per pound of coal burned, to raise the temperature of this water from 40 to 250 degrees requires $211 \times 9 = 1899$ heat units; but to raise the water from 100 to 250 degrees requires only $151 \times 9 = 1359$ heat units. As noted above, the total amount of heat that may usually be recovered from the gases per pound of coal is 1596 heat units, which is less than can be used in feed-water from out-of-doors in winter weather, but more than is necessary where steam is used to preheat the feed. The figures given for heat recovered by economisers are based on the assumption that we have an economiser of ample capacity in any given case, and represent about the largest saving to be expected in regular practice.

If engines are operated non-condensing for some good reason, the feed-water being regularly heated to about 200 degrees by the exhaust steam, and there is no other purpose to which the exhaust steam can be put, the saving as to feed-water to be made by the economiser does not warrant one large enough to extract the amount of heat indicated from the gases. In such a case it would be well to raise the temperature of the feed-water to about 300 degrees in the economiser. To heat water, under the proper pressure, from 200 to 300 degrees requires 102 heat units per pound, and with nine pounds of feed-water per pound of coal burned, the capacity of the feed-water would be for $102 \times 9 = 918$ heat units. The reduction in the temperature of the gases from 600 degrees, under the above conditions, would then be $(918 \div 3192)\ 600 = 168$ degrees, so that the gases would leave the economiser at $600 - 168 = 432$ degrees, or $432 - 300 = 132$ degrees above the temperature of the feed-water, which difference of temperature is a greater one than is necessary. For this last case a comparatively small economiser would do the work.

In most instances, however, all the heat that can readily be obtained from either exhaust steam or the flue gases is desired for general heating purposes or for industrial operations. If there be no exhaust steam, or if it be all desired for heating purposes, the flue gases will usually furnish enough heat to raise the feed-water from its out-of-door temperature to above 200 degrees. If a part of the exhaust steam be used to heat feed-water, the flue gases will raise it to

a still higher temperature, and will also heat surplus water for other purposes.

Large plants are in some cases heated by the flue gases, and this can be done in either of two ways. One plan is to install hot-water heating pipes and connect them with a part of the economiser arranged for the purpose, so that the water circulates through the economiser and the piping as it would through the piping and a hot water boiler. Where the hot air system of heating and ventilation is desired, suitable hot water coils may be connected with that portion of the economiser devoted to the purpose, and the air to be heated is passed over the hot water coils in a brick or iron compartment.

It should be noted that the recovery of heat from the flue gases makes available, for useful purposes, energy that would otherwise be wasted in the open air, and almost all of the energy so recovered is a clear gain. The only material objection to be urged against the use of economisers is that by their reduction in the temperature of flue gases they may seriously lessen the chimney draught and so interfere with combustion in the boiler furnaces as to more than offset any saving of heat from the flue gases.

The reduction of draught may well be a serious matter, and operate to the exclusion of economisers if it cannot be readily counteracted. Chimney draught is a result of the difference in weight between the column of heated air in the chimney and an equal column of the air outside. The movement of air is set up directly by gravity, the force of which is measured by the difference in weight of the inside and outside columns of air. As air and other gases grow heavier per cubic foot as their temperature is lowered, the heat taken from the flue gases leaves the gas inside the chimney more nearly equal in weight to the air outside. The draught pressure is affected by the height of chimney as well as the temperature within it, and a reduction of the heat in flue gases can in some cases be offset by an increase in chimney height.

In many instances, however, it is not desirable or practical to make an addition to an existing chimney, or build a new one high enough to give the required draught pressure with flue gases at temperatures which they have on coming from economisers. If these are to be used in this last case, it is necessary to provide mechanical means to move the gases up the chimney, and it is pertinent to compare the energy required for this mechanical movement with the amount extracted from the gases by the economiser. It is seldom desirable in practice to build a chimney more than 150 feet high, as the desired results can usually be attained at less expense with one or more chimneys of about this height than with one of much greater elevation.

The combustion of one pound of coal, under usual conditions, was shown above to produce 25 pounds of flue gases, and to raise these gases to the top of a chimney 150 feet high requires work to the amount of $25 \times 150 \times 1.5 = 5625$ foot-pounds, using the factor 1.5 to cover losses by friction. The combined efficiency of boiler, engine and fan to deliver the flue gases to the top of the chimney may be taken at about 2.8 per cent., so that to do 5625 foot-pounds of work on flue gases the equivalent of $5626 \div .028 = 200{,}928$ foot-pounds must be developed as heat by the combustion of coal. Since 778 foot-pounds are equivalent to one heat unit, the work of mechanical draught under the conditions stated requires the expenditure of $200{,}928 \div 778 = 257$ heat units per pound of coal burned. It was shown above that the reduction in the temperature of flue gases from 600 to 300 degrees by economisers effects a saving of 1596 heat units per pound of coal burned. The energy expended for mechanical draught is, therefore, only $257 \div 1596 = .15$ or 15 per cent. of that recovered by economisers under the above conditions. It should be noted, moreover, that, as the flue gases are reduced to a temperature of only 300 in the above case, they still have much value for draught production, and the work remaining for the

engine and fan is less than the amount named.

It should not be understood, however, that mechanical equipment for draught production is necessary in all cases where economisers are used, as the intensity of draught and the temperature of flue gases necessary to produce the desired results depend on several factors, such as the kind of fuel, the amount burned per square foot of grate, construction of boilers and the flue area, as well as the height of chimney. In any event, the temperature of the gases from an economiser will furnish a considerable portion, if not all, of the necessary draught, and the energy recovered will be large, compared with that expended for mechanical draught production.

In addition to the saving of fuel, economisers effect a direct increase in the capacity of a given boiler plant and furnish a reserve power of much value where loads are subject, at times, to a rapid increase, as in electric light and power stations. The high temperature to which feed-water is commonly brought by economisers and its comparatively slow movement in them lead to the deposit of substances that usually form boiler scale, but the removal of scale from economisers is made comparatively easy by their structure.

Economisers usually consist of one or more banks of tubes, so arranged and connected that the flue gases pass over their surfaces on the way from boilers to the chimney and that water for feed or other purposes is pumped through them. Means are provided by which all tubes are regularly scraped, as deposits of soot greatly reduce the value of the economiser heating surface. Free access is provided to one end of each tube, in order that deposits of scale also may be readily removed. In the average heating and power plant by discharging boiler gases directly into the chimney fully 25 per cent. of the heat energy from coal escapes into the air, and from one-half to three-fifths of this loss can be turned to useful work through the agency of the type of apparatus here considered.

THE MODERN MACHINE SHOP

By Joseph Horner

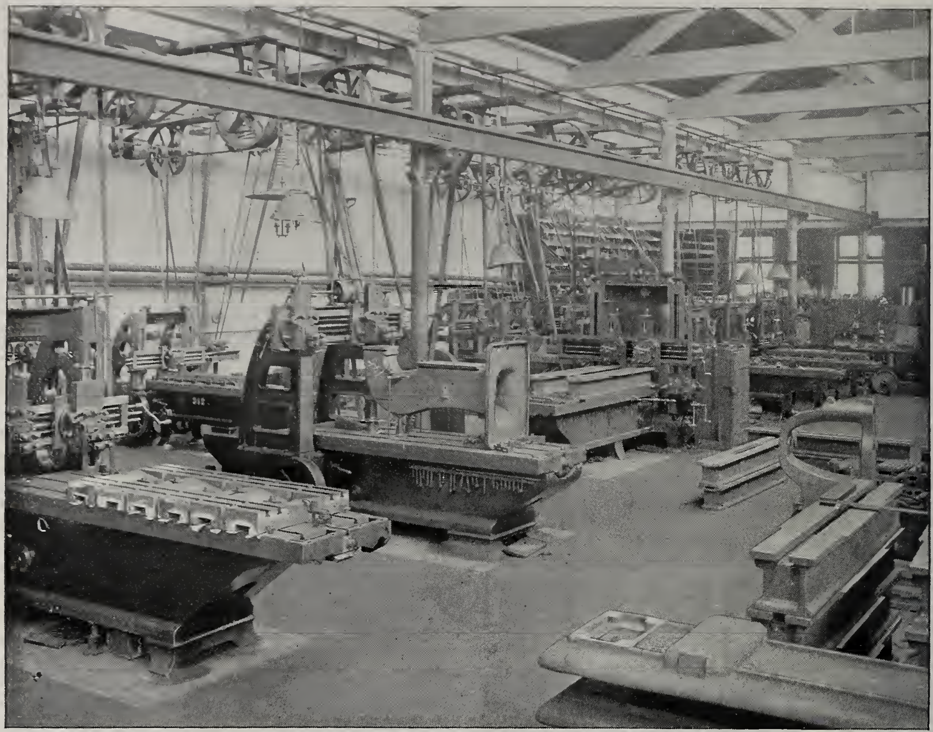
THE machine shop is, as a rule, the most important department in the modern engineering establishment, whether we regard its opportunities for economy of production, its immense volume of output, the heavy cost of its plant, or its scope for development. Formerly the machine department occupied a more subordinate position, being of rather less account than that of the millwright, or the fitter. This is now reversed. A vast revolution has been effected during recent years, until at length firms are realising,—and this has come as a very sudden revelation to many,—how profoundly former conditions have been changed, and how widely the practice of the present day is divided from that of only a few years since. The fact, too, is beginning to be realised that the craftsman has, in a very large degree, become merged and obliterated in the machine.

The present period is one of renascence, and not of stability; and it will, therefore, of necessity become a period of rich development. The most important economical advances in the near future will certainly lie in the machine department. Here the greatest recent economies have been effected; here, therefore, the chief interest will centre in the opening years of the coming century.

It is proposed to take a general survey of the conditions which control the work of the machine shop, and in treating this subject we must study the diverse operations and machines, the changing relations, economies, results, arrangements, and the future. To attempt to classify machines becomes increasingly difficult, because with modern specialisation these become more of a composite character, so that sharp border lines of distinction are often obliterated. It is impossible now, without very much qualification and elucidation, to denote a machine as a lathe, a planer, a shaper, a gear cutter, a milling machine, or a screw machine. Furthermore, since for a good many operations the services of either one can be selected out of three or four different types of machines, and since, in this choice, the judgment of the foreman or manager is exercised, the subject of tooling has to be approached from the point of view of operations and results, rather than from that of machines.

We consider, therefore, in the first instance, the natural classification of the operations performed in the modern machine shop, and the broad correspondencies with them of the types of machine tools. Very broadly this work may be classified thus:—The production of (1) plane surfaces; (2) circular surfaces, external and internal; (3) curved surfaces of both regular and irregular outlines; (4) curves in combination with planes in which may be included specially the teeth of gear wheels; (5) the production of all kinds of screw threads. This is a simple, but comprehensive, classification. It does not coincide with any classification of machines, but is, nevertheless, a convenient arrangement.

In the main, however, the production of plane surfaces includes the operations of all types of planing, shaping, and slotting machines, the facing operations of lathes, and arboring done on drilling machines. Making circular surfaces includes turning done in lathes of all types, boring performed on lathes and in boring machines, besides circular



PLANERS IN THE SHOP OF A. HERBERT, LTD., COVENTRY, ENGLAND

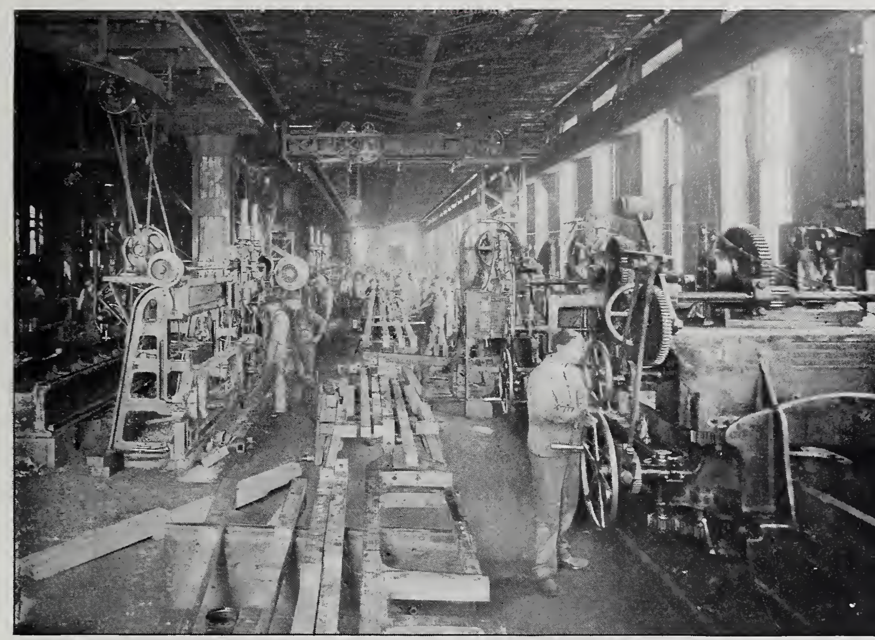
slotting, circular milling, and drilling. Curved surfaces of regular and irregular outline are shaped by planing, shaping, slotting, milling and profiling, the curvilinear movements being effected by partial rotation of tool holders, or of tables, or through the agency of forms, or formers, or cams. Tooling producing curves in combination with planes is effected in the machines just named by the same methods, and also, in the case of gear wheels, by means of circular milling cutters, or with single-edged planing tools, guided by formers. The production of screw threads includes a wide range of operations performed in a variety of machines, ranging from the screw-cutting lathe to the extensively specialised screw and chasing machines. The threads are cut with single tools, operated either by change wheels and screw, as in the lathe, or by master screws, or hobs, as in the Fox, and stud and stay lathes, or by chasers or comb tools or discs, as in the screw machines. The capstan or turret lathes embody provisions in the various tools set around the turret for turning, boring, screwing, milling, and cutting off. In the cutting of screws, or, strictly speaking, spirals of very long pitch, as those which form the teeth of long axial mills, change wheels in combination with a traverse movement impart the spiral. Grinding also is applicable to nearly all the operations named above, chiefly in imparting final corrections to work already machined and hardened, in addition to the indispensable functions of the formation of cutting edges.

One of the principal differences between the methods of the older and the modern machine shops is that operations in the latter have been expedited by considering them less in relation to machines than to ultimate results. Side by side with the old machines there are now ranged many new ones. The functions of the lathe, the planer, the shaper, the slotter, and other so-called standard

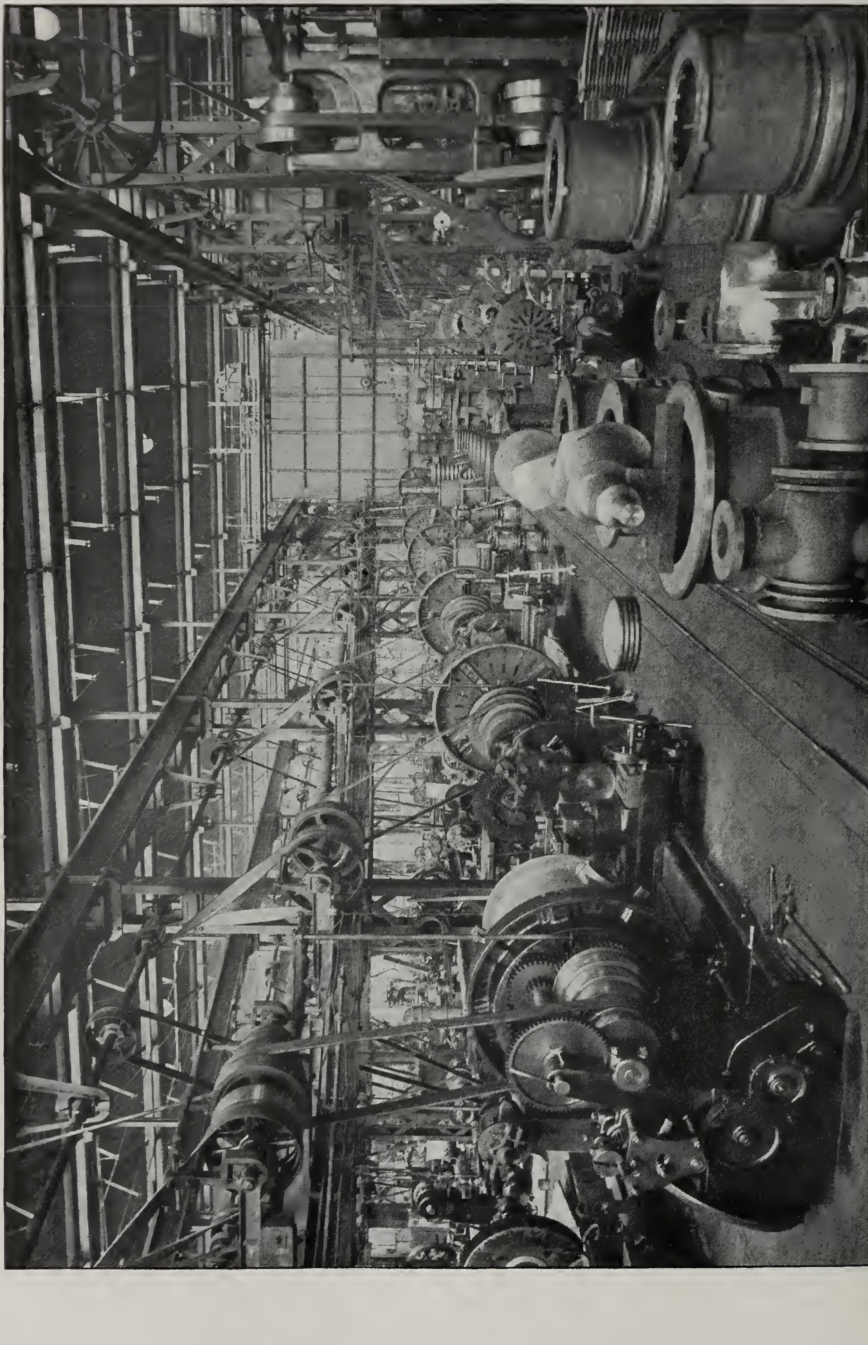
tools which dominated the shops until recently have been deeply invaded. As in moulding and forging, so in machinery there is nearly always now a wide choice of methods, with which the mechanical results will be similar, but the economical and commercial results very diverse.

In the tooling of any surface it is obviously a matter of no importance in regard to the mechanical results whether the tool moves and the work remains stationary, or whether the tool remains stationary and the work moves. Neither does it matter whether a surface is tooled by a narrow cutter and traverse feeding, or by a broad cutter fed normally to the surface without traverse feed; nor whether a cutter is a point or an edge, using the terms in the shop sense; nor whether a cylindrical cutter operates on its end or on its periphery. Neither does it affect ultimate results whether a plane surface is tooled with a narrow reciprocating cutter or with a revolving mill, or whether convex or concave surfaces are produced by one or the other method. The same might be said of many outlines and the operations by which they can be produced. But,—and this is a most vital point,—the adoption of one method instead of another often does make a most important difference in the cost of production.

Clearly, therefore, every piece of work must stand by itself. In fact, it is often necessary to give alternative methods full trial before settling on the regular way of machining to be thenceforth adopted. In some cases the best results will be obtained by multiplying cutting operations on one machine without shifting the work. In others, by changing the work in the same, or into other machines. It is detrimental to the accuracy of some articles to move them; or, in other cases, shifting takes some considerable time. A leading feature, therefore, which is embodied in many machines of modern design is provision for tooling as much as possible without resetting on different, or on the same, machines. In other jobs there may even be an advantage in shifting



THE MACHINE SHOP FOR LOCOMOTIVE FRAMES AT THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA, PA., U. S. A.



A LATHE BAY IN THE MACHINE SHOP OF MESSRS. WILLANS & ROBINSON, LTD., RUGBY, ENGLAND

the work, and the operation may be effected almost instantly.

These changing relations of the older and the recently developed types of machine tools, considered from the point of view of the work done upon them, should be clearly understood and accepted by the management under present competitive conditions.

But threatened lives live long, and so the standard planing machine, shaping, and slotting machines survive, notwithstanding that much of their work has been appropriated by the milling machine. When very heavy work is in question, the rectilinear machines still hold their own. In light work, and even in that of medium dimensions, the advantages of the milling machine become evident, particularly when the question is one of tooling irregular surfaces by heavy roughing cuts, using cutters with staggered teeth, or slabbing cutters with inserted teeth.

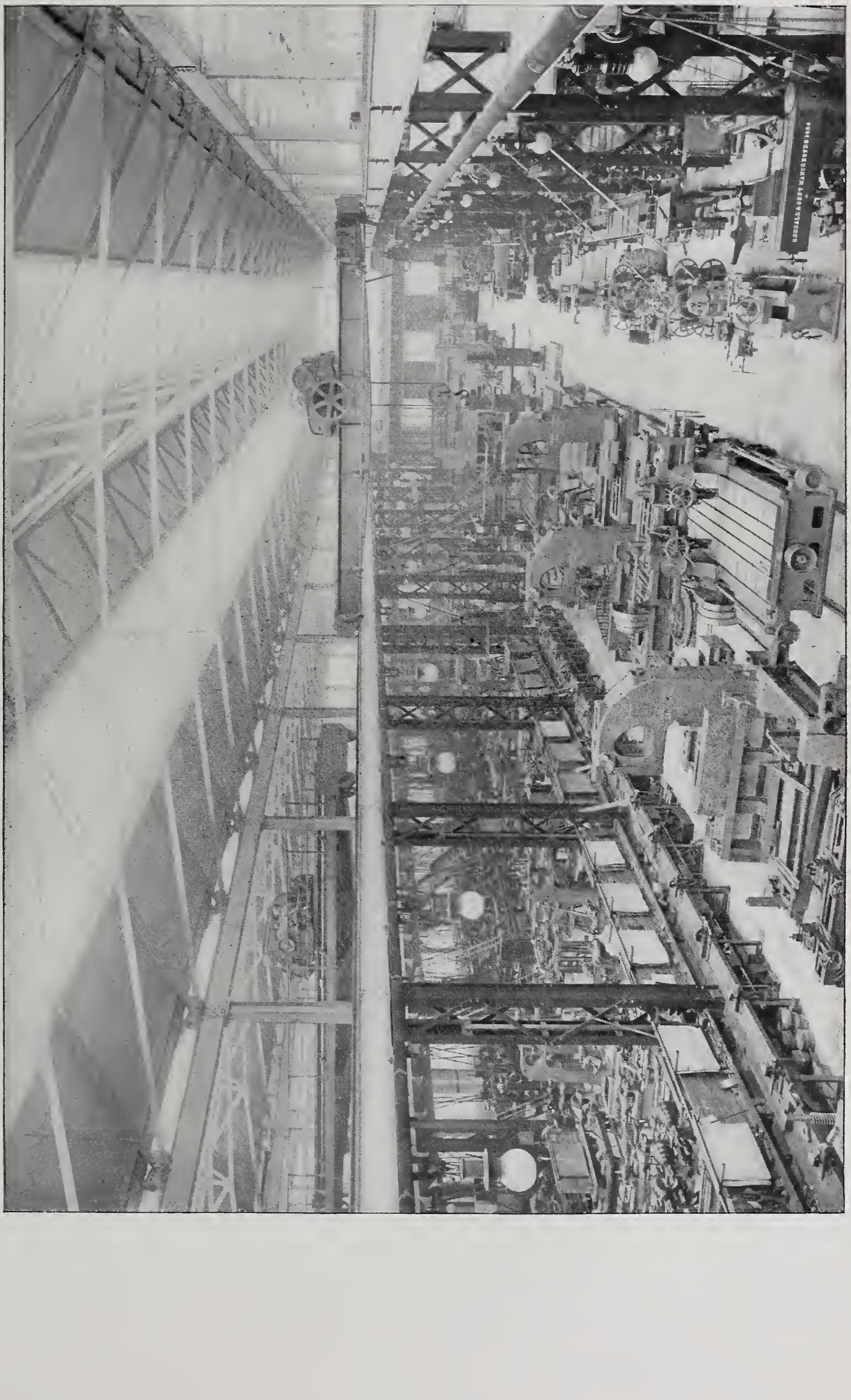
When profile milling, either with single mills or gang mills, is in question, the planing machine is not to be considered. But, on the other hand, the rivalry of the milling machine has been the occasion of, and stimulus to, the improvement of the reciprocating machines; and the quick return of four to one, and in some cases a higher ratio, and the rapid striking gear together, with minor improvements in design, have made the planing machine of today a far more efficient tool than its predecessors. There are also shapers with automatic down-feed and stop movement to the head.

The slotting machine has suffered more in the growing competition than the planer and the shaper. One extensive section of the work of this machine, —the cutting of keyways,—is being now appropriated by the various keyseaters. Much of the circular and irregularly shaped work formerly slotted is also now done more accurately on profile milling machines, which have been extensively developed in recent years, and are likely to be more so. These supersede the slower work of the slotter and shaper which often require several resettings in order to get around the various profiles, straight and curved; and any number of similar pieces shaped by a former will be of identical dimensions. The illustration on page 390 represents a fine specimen of the best British practice in heavy profiling machines.

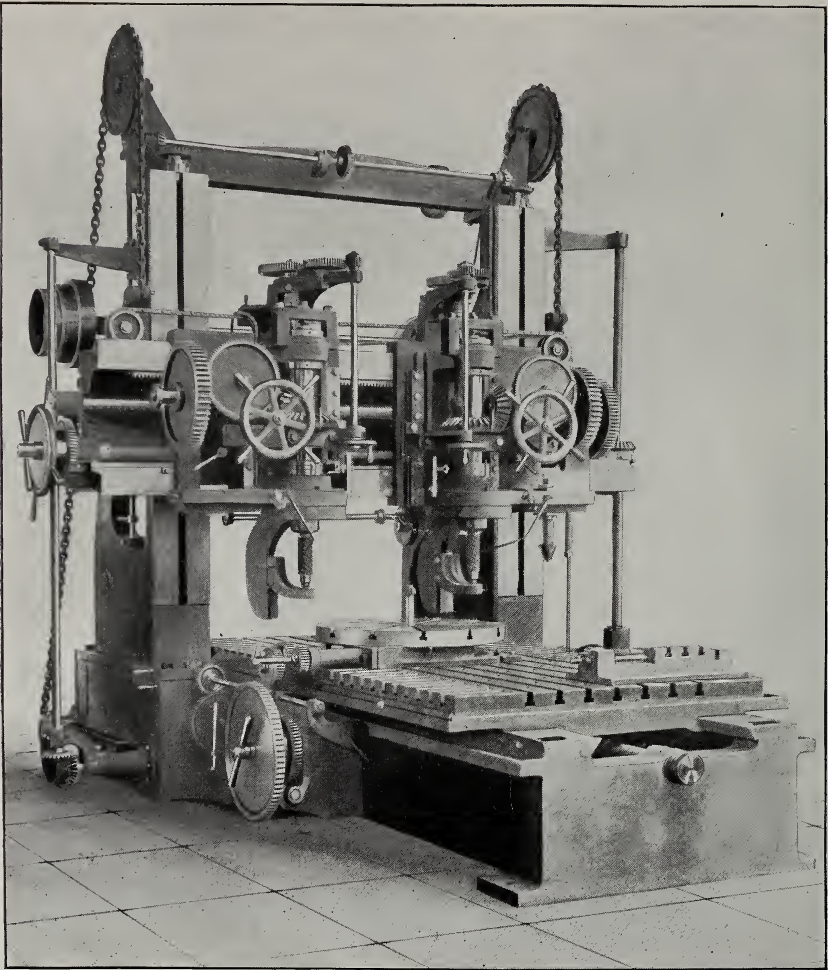
But the most remarkable departure in machine shop practice during recent years has been the great advance in turret work. The turret lathe is to the standard type what the milling machine is to the reciprocating machines just named. Within half a dozen years its capacity has grown from that of rod work of very moderate diameter and length to heavy bar work of great length, and the tooling of castings, even of considerable size. The Jones & Lamson turret lathe (see page 395) was apparently the first in which a length of 24 inches could be operated on by the turret, the flat design of which was an absolute novelty. This most successful innovation has been quickly followed by other machines of equal capacity, and, in some respects, modelled upon it. The Gisholt lathe at about the same time provided successfully for the tooling of castings considerably larger than those which had hitherto been attempted; this by a very massive turret with six holes, and a cross-slide with a square turret for four tools; and now there is a British machine fully equal to the Gisholt in power and capacity built by A. Herbert, Ltd,—a great hexagon turret lathe, weighing $4\frac{1}{2}$ tons, having an 18-inch inclined turret, with faces $10\frac{1}{2}'' \times 7\frac{1}{2}''$, pierced with $3\frac{1}{4}''$ holes. An illustration of this appears on page 393. When castings of small and of moderate dimensions have to be turned in quantity, they can be chucked from a magazine attachment, and operated on with tools held in a turret, and on a cross-slide. The era of tooling castings in this way is in its infancy. It is bound to advance and oust such work from the common single-tool lathe.

Machines of this type are rigged up both with single tools and with boxes of tools, just as when bar work has to be done. But two tools are usually cutting at one time, one on the main

THE NEW MACHINE SHOP OF THE GENERAL ELECTRIC CO., SCHENECTADY, N. Y., U. S. A. A GOOD EXAMPLE OF ELECTRIC DRIVING



A SHOP VIEW AT THE WORKS OF MESSRS. KENDALL & GENT, MANCHESTER. THE TOOLS ARE ELECTRICALLY DRIVEN IN GROUPS, MAINLY BY 20 H. P. MOTORS



A LARGE PROFILE AND GENERAL MILLING MACHINE, BUILT BY MESSRS. WM. MUIR & CO., LTD., MANCHESTER, ENGLAND. DISTANCE BETWEEN UPRIGHTS, 5 FEET 6 INCHES. SPINDLES, 4 INCHES IN DIAMETER

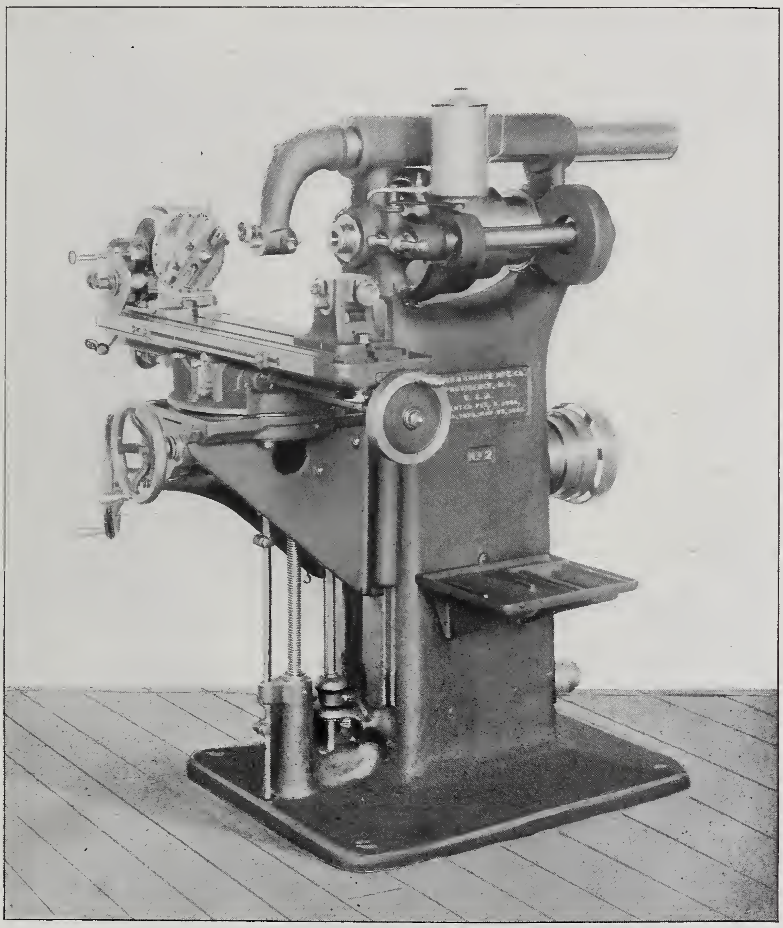
turret and one on the cross-slide turret. The Herbert machine, too, affords the latest example of the enormous stiffening of modern machine tools, of which the big screw machines of this firm are well-known types.

The increased power demanded of tools has resulted in this,—that among leading firms we find more metal being put into machines, broader wearing surfaces, bigger spindles, and increasing care bestowed on the means for adjustment. We also observe in many designs the lessening of overhang which produces strains due to leverage, and the bringing lower down of parts on which such strains occur. Also the keeping of alignment stresses as much in line as possible, making division wheels and rings as large as convenient, and bringing locking pins as far away from the centre as practicable,—points which conduce to steadiness and stiffness in working and to accuracy. There is also the casting of heads of machines solid with their beds, and the bestowal of greater care upon outlines which correspond with intensity of stresses.

The extension of turret practice goes on so rapidly that we find the manufac-

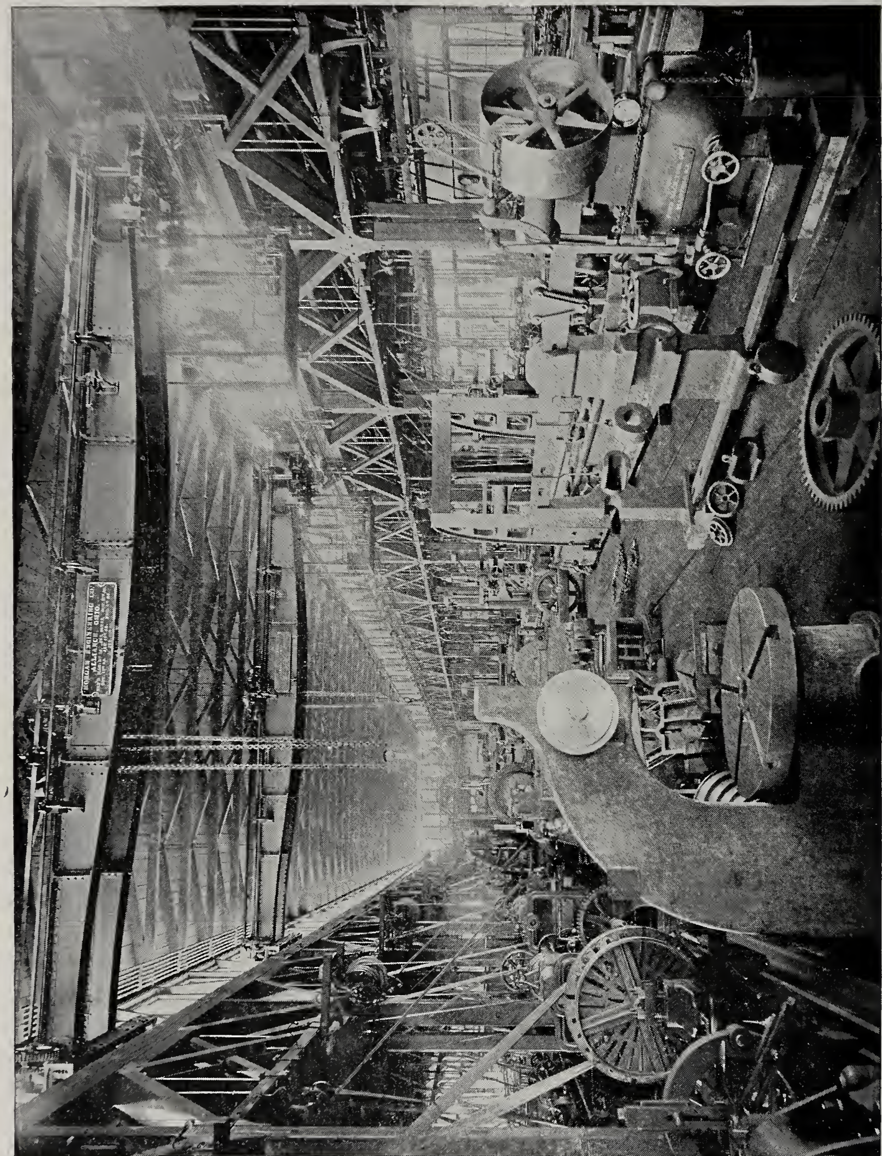
ture of turret lathes gives full employment to many firms, a few of whom confine their energies to the manufacture of a single type only, in different sizes. The general extension of turret work to lathes of nearly all kinds, including the vertical type, and even to drilling machines, is proof how greatly in setting tools in the slide rest, or in changing work from lathe to drilling machine.

It is difficult to write with adequate scope of the practice of milling in general in the space of a paragraph or two. It affords one illustration, among others, of a practice of which the origin goes



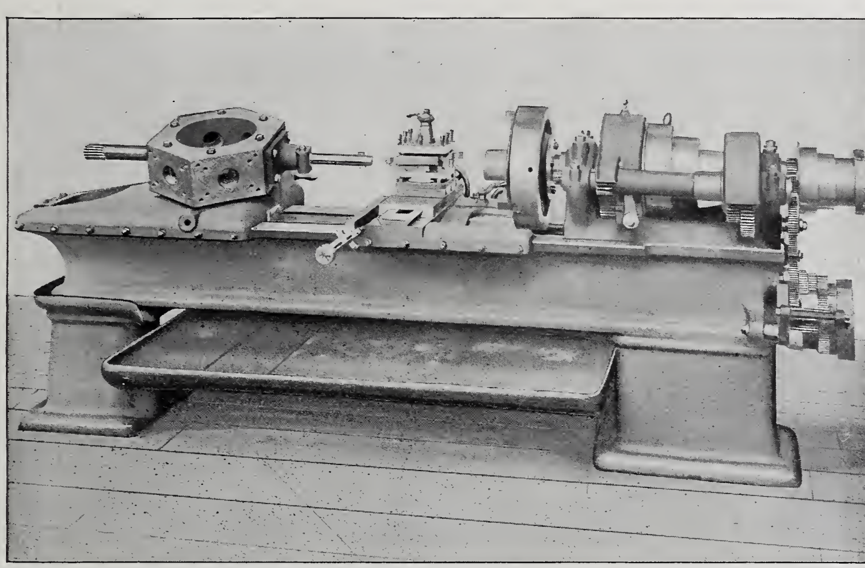
UNIVERSAL MILLING MACHINE, MADE BY THE BROWN & SHARPE MFG. CO., PROVIDENCE, R. I., U. S. A.

this has been neglected hitherto. Although turret work lends itself best to repetition work, yet it is not to be despised in the work of the general shop, as witness the chucking turret lathe; for since it will hold drills, reamers, turning and boring tools and threading tools, its employment saves a deal of trouble back somewhere about a century, and which, neglected in Great Britain, became greatly developed in America, and the full economical value of which is only being generally recognised at the present time. To speak of a milling machine tells next to nothing, for it now occurs in nearly as diverse forms as that



THE MACHINE SHOP OF THE POND MACHINE-TOOL WORKS, PLAINFIELD, N. J., U. S. A.

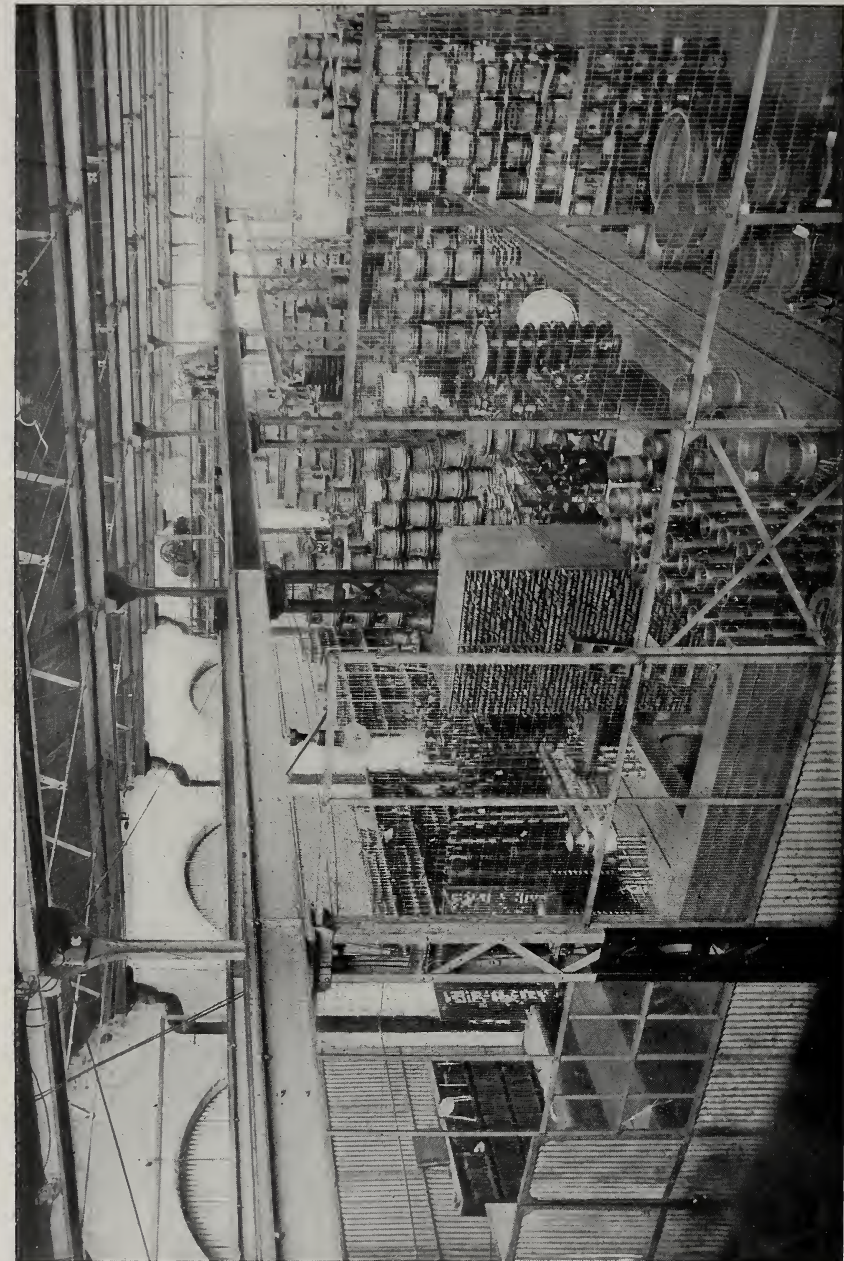
protean machine tool,—the lathe. The Universal type is the best known, but though capable of performing an immense range of work, it is greatly limited in regard to dimensions, and has, therefore, a somewhat restricted range of utility in the highly specialised machine shop of to-day. For the lighter classes of work it is invaluable, but when we get away from these the heavy planomillers, so called because they are built on the general lines of the planing machine, provide the means by which work of great length and considerable breadth is tooled on horizontal surfaces, vertical edges, and, in many cases, on angular edges.



A TURRET LATHE FOR HEAVY CASTINGS AND BAR WORK. MADE BY A. HERBERT, LTD., COVENTRY, ENGLAND

The cutting of gear wheels is another department of machine shop practice which has received considerable impetus latterly. But half a dozen years ago it was in a very low state in Great Britain, comparatively few cut gears being used, and those often were far from accurate. That matters have mended is due in large measure to the high degree of excellence of American gear cutting machines, and to the demands of the chainless cycle and motor car trades. A number of American machines of this class have become more familiar in British shops than machines of British make, which have been generally lacking in automatic arrangements.

Though a high degree of accuracy has resulted from the use of standard gear cutters, the practice of wheel cutting has not yet attained its majority. For the later developments point continuously to the fact that specialisation is destined to rule here as much as in the work of lathes and other machine tools. The automatic spur gear cutter has been brought to a high degree of perfection, and now later machines are constructed for the cutting of bevel wheels only, by planing or by generating,—a department in which it is certainly singular that rotary cutters should so long have been employed, rendering necessary subsequent easing with the file. The Bilgram generating machine, of which an illustration is given on page 396, and the various recent gear planers are clear indications of the trend of practice. The latest developments are some American machines which are designed to plane one size of bevel wheel only. Multiple gear cutting is another late development. It is applicable to spur



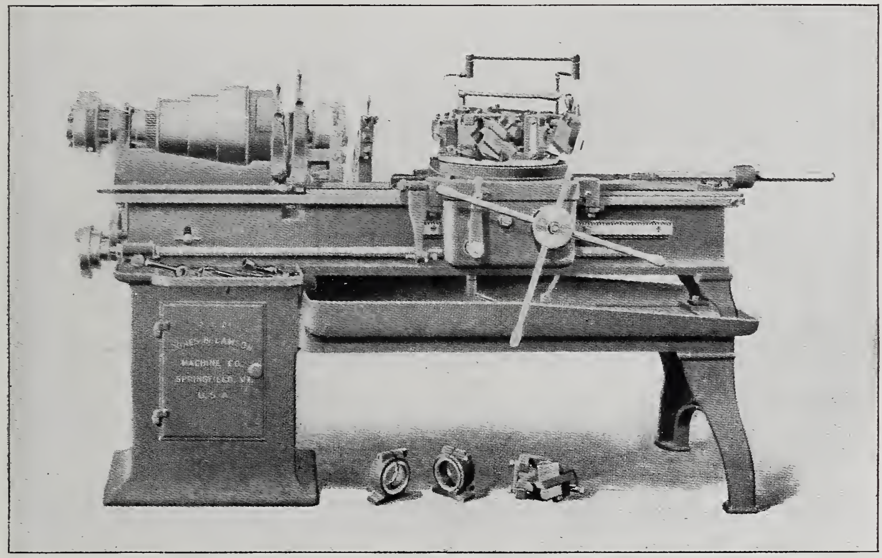
A CORNER IN THE MANUFACTURED STORES DEPARTMENT AT THE WORKS OF MESSRS. WILLANS & ROBINSON, LTD., RUGBY, ENGLAND

wheels and racks, and here, too, special machines take wheels up to a certain diameter, and others a number of racks of a given length and thickness.

Another recent growth is that of formed work in connection with brass finishing, taking the place of hand-operated tools. In one class of lathe the irregular profile is shaped through the medium of a former, bolted behind the lathe, against which the tool-slide is pressed. In the other the cutting tool is shaped to the section required, and the end, being ground to a cutting angle, takes off a chip of the full width of the tool, thus shaping the article at one operation.

Accurate grinding is another modern development of the machine shop. Irregular contours are ground accurately by the assistance of cams, and spindles and bearings within very fine micrometric limits. Cutter and tool grinding is done to precise angles, without skilled attendance. In short, the emery-wheels of a few years ago have given place in the best shops to high-class grinding machines of various types,—accurate, and beautiful in their mechanisms. The ncessity of accurate grinding machinery in the modern shop is clear from a consideration of the foregoing conditions. Machine spindles can be fitted accurately only in this way, and drills, reamers, milling cutters, etc., can be produced true and kept in order to gauge only by grinding.

The designs of these modern tools which produce such great economies in the machine shop practice of the present day are found, when studied closely, to embody aggregations of many minor details. In short, they are so valuable because they are so highly specialised.



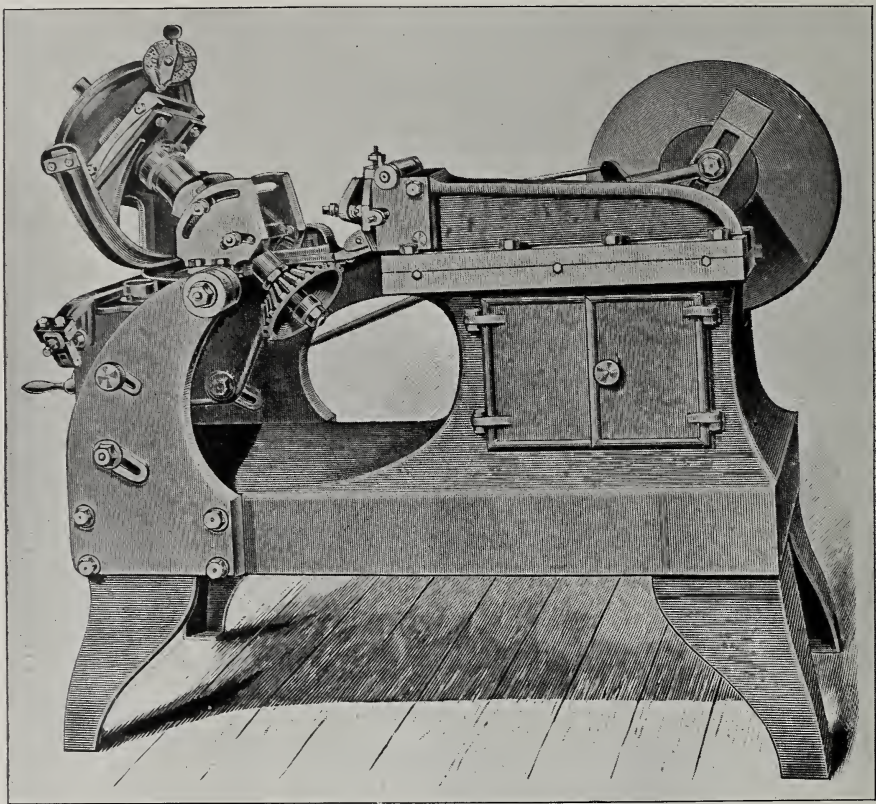
A TURRET LATHE MADE BY THE JONES & LAMSON MACHINE CO., SPRINGFIELD, VT., U. S. A.

The machining of work is economised by duplicating tools. The oldest example of this occurs in the duplex type of lathe, in which two, and in later practice three, four, or even six tools may, in extreme instances, be operating at one time. Similar illustrations occur in the employment of two tools in planing and in slotting machines; in the carrying on of two or three sets of milling operations at one time, as on some of the plano-millers; in the boring of two or more cylinders simultaneously; in the cutting of several rack teeth at once on several adjacent racks; in the Eberhardt system of cutters for spur wheels,

by which two teeth and upwards are cut at one time; and also in the numerous multiple drilling machines.

The machining of work is also economised to an equal extent by operations which are not simultaneous, but in which a number of tools are brought round in quick succession, as in turret practice, and in which also time is saved which is otherwise occupied in resetting work and adjusting tools. Time is also saved by the use of stops, by which the traverse of each tool in the turret is limited and arrested without any care on the part of the attendant. In the modern turret, instead of one stop doing duty for all the tools, which involved careful setting of every tool in relation to the stop, every tool has its own independent stop, adjusted to accommodate the tool.

Facility for rapid changing of feeds is another late development which is conducive to rapidity of output. The old devices of altering change gears, or of shifting feed belts, are now recognised as being too slow in operation for the smaller lathes and milling machines. A good many firms, therefore, now embody in their tools devices to change feeds rapidly. The principal among them is the nest of gears, having movable pinions of different sizes, which are slid into gear with fixed pinions by means of a cotter or pin in a sliding rod, which pin drives in the loose pinion through the bosses,—a device put on many horizontal and vertical lathes. In other cases pinions are hinged, to be thrown over into gear and there locked. Another rather common device is the Sellers friction discs, in which the radial position of the inner solid disc to the



GEAR CUTTING MACHINE MADE BY HUGO BILGRAM, PHILADELPHIA, PA., U. S. A.

THE STORE ROOM FOR FINISHED PRODUCT AT THE WORKS OF A. HERBERT, LTD., COVENTRY, ENGLAND

outer divided pair regulates the feed. Then there is the bowl type of disc, in which the radial position of the friction roller to the large disc determines rate of feed. These are well known, but their rapidly increasing application to machines other than those for which they were originally designed is a feature which makes for economical working. No time is lost in making changes, and there is, therefore, no excuse for running a machine at a speed which is not the best possible,—a point of much importance in facing work of varying diameters.

Speeds obtained by cones and back gear are doubled by doubling the countershaft pulleys,—a device adopted for the driving of many machines, and which, when fitted in conjunction with friction-geared heads, puts the older slow arrangements out of the running. The friction-geared head was applied, in the first place, rather sparingly to the turret lathes of a few makers, saving in the aggregate a deal of time otherwise occupied in throwing back gears in and out. The last two or three years have witnessed a remarkably rapid development of this most handy device.

In the modern shop a large proportion of screw cutting is transferred from the standard lathe with lead screw and change wheels to the chasing lathe, fitted with removable hobs of different pitches at the front of the lathe. There is also the rapid reversal of motion of a lathe carriage, effected without going to the head stock to perform it.

The use of the hollow spindle conduces to great economies. If repetitive work, under, say, about 2 inches in diameter, has to be turned, then it is cheaper to turn it from a bar passed through a hollow spindle of a turret lathe than to make separate forgings, even though the latter should be stamped in dies. The material cut away and wasted is of much less value than the cost of forging, or of chucking each single piece. And if work cannot be passed through a hollow spindle, but must be chucked in short lengths, then it is generally cheaper to saw off pieces from a bar with a power hack saw than to forge. We have, moreover, the transference of the drilling of all small holes from the heavy machines to the

THE TOOL-MAKING DEPARTMENT OF MESSRS. GREENWOOD & BATLEY, LTD., LEEDS, ENGLAND

light, sensitive, high-speed drills, with balanced spindles; and the removal of boring from the lathe to the boring machine having an adjustable table.

A further extension of economy, though of limited degree, is seen in some machines which combine provision for both milling and drilling; for drilling, boring, and tapping; for planing and drilling; boring and slotting, and so on. Yet another economy is practised in duplicating machine tables, so that the setting of work will be proceeding on one while the other is in operation,—a device embodied in some planing and drilling machines.

Lubrication receives more attention than of old when the drip can, and soap and water afforded the only means for preventing the heating of cutting tools. The centrifugal pump, and the oil spreader attached to the automatic machines is still a novelty in a good many machine shops, as is also the oil separator and oil filter, while the oil pipe lines for supplying a gang of automatics is an arrangement comparatively little known as yet. The value of abundant lubrication is evident in the great chips which are removed when the lubricant is flooded over the cutting edge and the work,—chips which would be impossible with the old drip system. Another point of great value is that the use of a separator permits of the economical use over and over again of the expensive lard oil, which is better in several respects than soapy water.

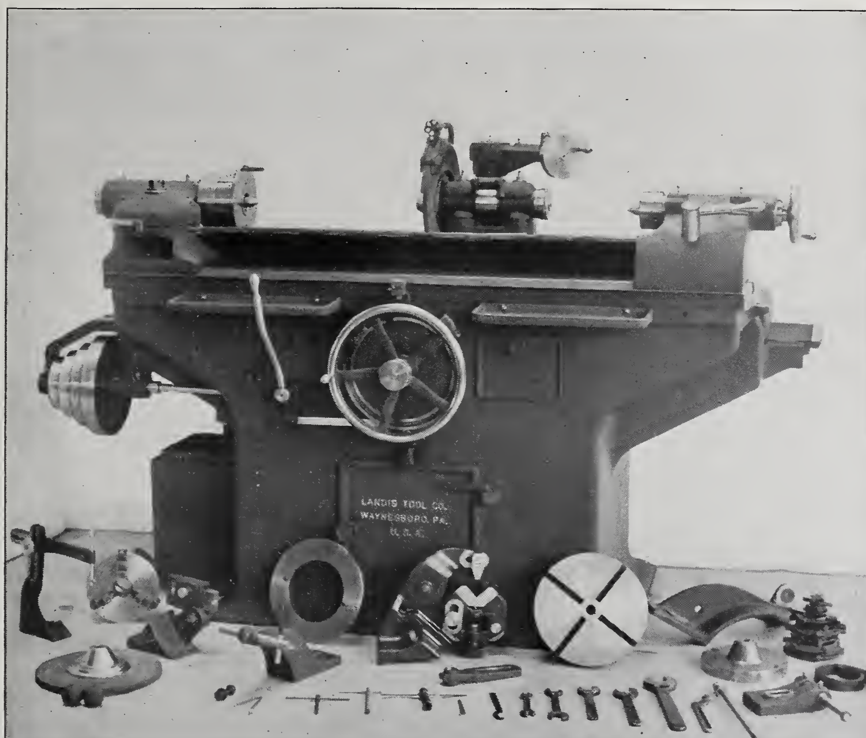
Another result of this abundant lubrication is, that less close attention need be given to tool angles than of old. There are many tools doing heavy work which should not do it, if tool angles alone were in question. But floods of oil, and abundant support both to the work and the tool, and a rigid basis in the framework of the machine produce results which would sometimes appear incredible but for an experience of these facts.

Machines, however, are but a means to an end. It is possible to have good modern machinery not utilised to the fullest advantage. This fact naturally leads to the consideration of the ultimate tests of economic practice which

are either the cost of production or the degree of accuracy of results attained; for these, after all, are the only tests of the judgment, or lack of judgment, involved in this case. And these economies will in some cases be dependent on the judgment exercised in the choice of various machines to produce identical ultimate results; in other instances they will depend mainly on the manner in which machines, including their tools and their setting, are operated.

The low cost of production, as tested by rapidity of execution, may or may not coexist with accuracy of results. Rapid tooling is often consistent with high limits of accuracy. But on some classes of work very fine precision would be thrown away. Nevertheless, the two are often confounded, and high-class machines are bought for doing work for which cheaper and less accurate ones would be equally suitable. The problem must properly always be one of means to an end. From this point of view there are many second-rate tools, solidly built, hand-operated in every detail, which, for rough and general purposes, are better adapted than high-class automatics and semi-automatics.

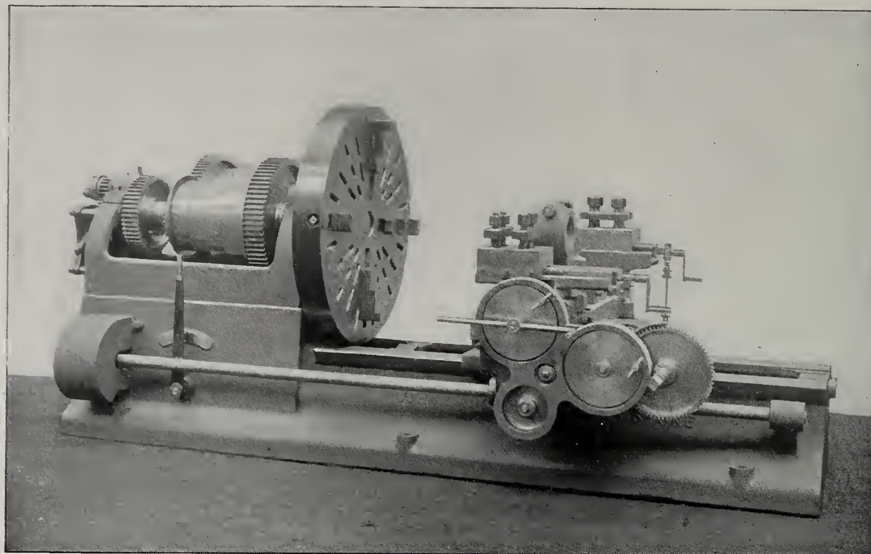
It is in these two aspects of rapidity of execution and accuracy of results that the work of the modern machine shop excels. All other issues are but subsidiary to these, and must be considered only from these points of view. There are, broadly, two distinct methods by which these results may be secured.



A GRINDING MACHINE MADE BY THE LANDIS TOOL CO., WAYNESBORO, PA., U. S. A.

One is to embody the necessary provisions in the design of a special machine; the other is to use a standard type of machine and fit suitable adjuncts or appliances to it.

The special types of machines are immense factors in rapidity of execution and economy of results, because, though



A SURFACING AND BORING LATHE WITH DOUBLE RESTS, MADE BY MESSRS. JOHN LANG & SONS, JOHNSTONE, NEAR GLASGOW

performing many times the quantity of work done by a single machine tool, they cost no more for supervision. Though designed for the performance of one operation, or two operations only, they are constructed with automatic mechanism, and often attain, through successive developments, the absolutely automatic stage at which they require no skilled attendance whatever.

From these points of view the question for firms to decide is not whether a machine-tool will do its work with precision merely, but whether it will perform it economically also. If there are machine-tools which are capable of performing twice, four times, eight times, or twenty times the quantity of work, with no added cost for supervision,—often less,—but with simply an extra outlay of capital, it is time to consider seriously the relegation of the wasteful tool to the scrap heap. A workman's wages are as big an item as the interest on a machine-tool, and if the wages of several workmen are saved by the purchase of a costly machine-tool, and if there is sufficient repetitive work in the establishment to keep the machine regularly occupied, then the interest on the capital outlay and the rate for depreciation will often be considerably less than the wages saved. Though the complexity and cost of a machine is in some degree inversely proportioned to the quantity of precisely similar work which it is designed to produce, the question is far less one of price than of gain in output. Employers of experience, therefore, seldom trouble much about cost alone. They want to know how much more or better work a machine will turn out than existing machines, by which alone its true money value is to be gauged.

But the employment of a special machine to perform simply one class of operations is generally justifiable only when there is sufficient work to keep it employed during the whole, or a large proportion of the time. Firms, therefore, who do general work chiefly, fall into error when they purchase highly specialised machines with the idea that they will conduce to economical output. The error is nearly as great as that of the specialised firms who enter into competition with their rivals with an equipment adapted chiefly to the general shop.

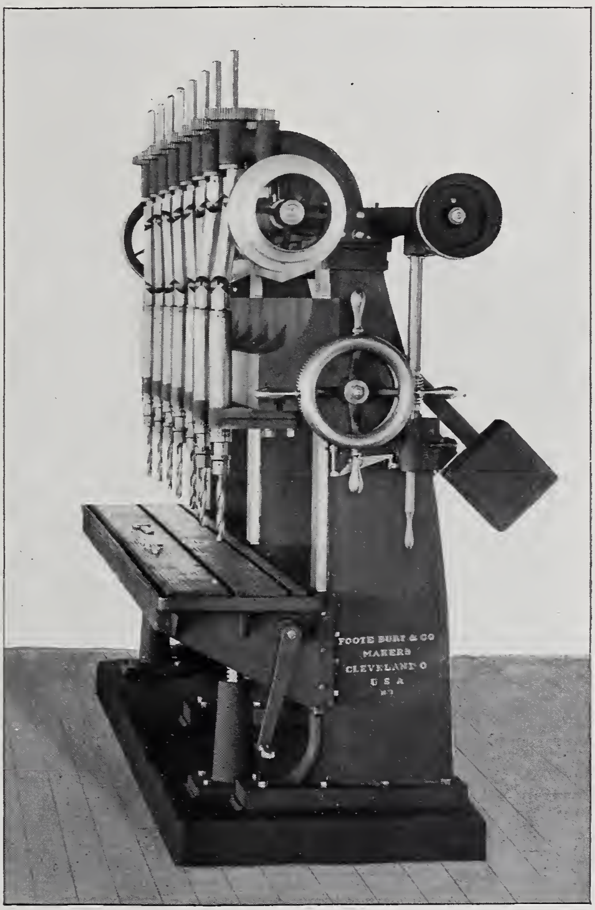
Nevertheless, the inevitable tendency in the development of machine-tools is to restrict the number of operations per-

formed on them. The universal machine has but a small sale by comparison with the special one. As specialisation increases, diverse work that was formerly carried to a single machine becomes apportioned between two, three, or more.

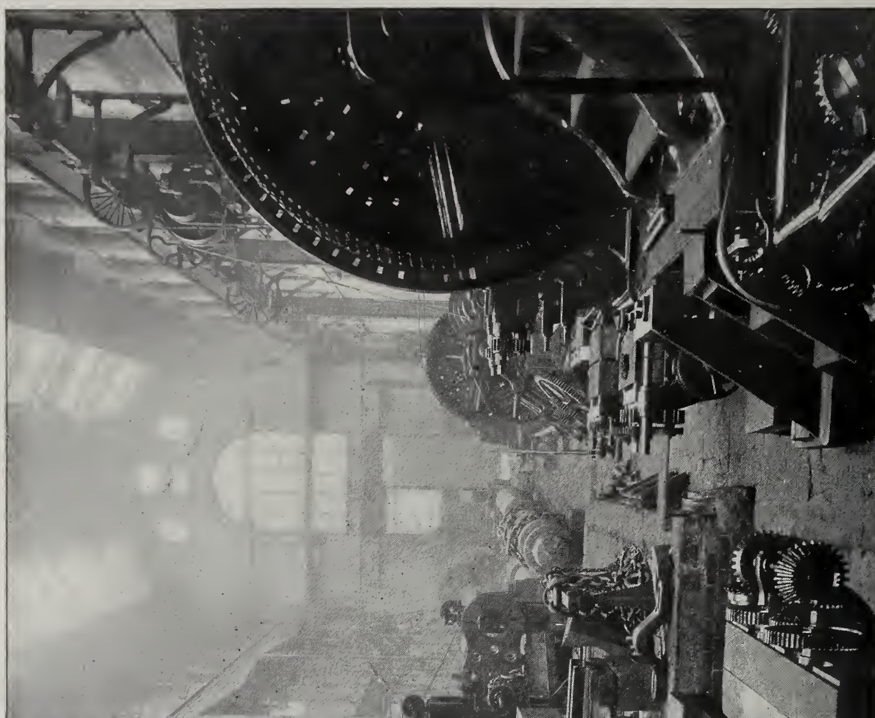
The second test,—that of degree of accuracy of results,—is partly a question of high-class machines, and partly one of careful fixing up of tools, and of multiplication of operations. The more exact the results required, the more exact must the tools be made and fitted to gauge, and the more numerous, as a rule, must the successive operations be. The grinding of drills and reamers to gauge, the careful fixing up of box tools, and the use of stops settle dimensions. But these must be used thus to ensure accuracy:—The tool that takes off the bulk of material will not finish to fine limits. This must be done by successive operations, each one removing a mere trifle of material without heating, straining, or distorting the work.

But accuracy of results depends, besides, in machine production, on the use of many adjuncts to machines, as jigs, templets, and gauges,—practice second only in importance to the design of special machines. Costly jigs, and templets, and gauges become indispensable in the modern system. These terms are used somewhat loosely. A short definition would define a jig as an appliance by which the machining of work is facilitated by enclosing it partly or wholly in the jig, which affords guidance to the cutting tools. A templet is, in its strictest definition, an article used for setting out work, and not a guide to cutting tools. A gauge is that by which work is measured after tooling has been done.

Jigs are used on nearly all machines, less on the more special and automatic types than on standard ones. When a large volume of similar work has to be done, for which the cost of very special machinery cannot be incurred, then jigs and templets, fitted on standard machines, afford invaluable aids to repetitive production. The drilling jigs and templets are by far the most common. The hardened formers used for profiling on milling machines constitute a large class in some shops where much cam



AN ADJUSTABLE EIGHT-SPINDLE DRILL, MADE BY MESSRS. FOOTE, BURT & CO., CLEVELAND, OHIO, U. S. A.



A MACHINE SHOP VIEW AT THE WORKS OF MESSRS. JOHN BROWN & CO., LTD., SHEFFIELD. A FORGING FOR A TWO-THROW CRANK SHAFT FOR H. M. S. "BACCHANTE" IS SHOWN ON AN 8-FOOT SLOTTING MACHINE AT THE LEFT

cutting is done. Speaking very generally, small work is tooled by jigs, large pieces of work by templets.

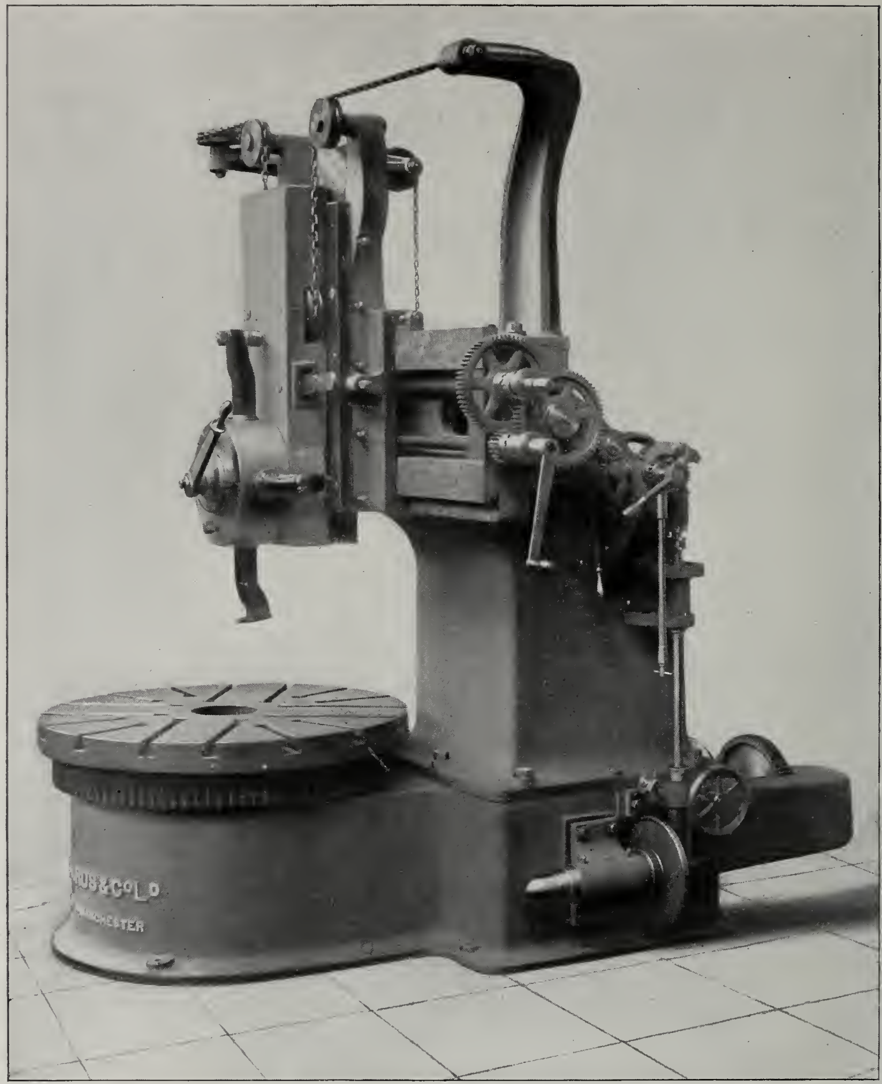
By the use of jigs the operations of machines are controlled without any further care, as far as measurement is concerned, on the part of the workman, and interchangeability of parts is secured. For example, the position of a drill or reamer may obviously be located with equal accuracy either through a hole in a block, embracing a piece of work on the table of a drilling machine; or by a drill in a turret in alignment with the work centred in a common lathe; or a chucking lathe; or in a pin and stud lathe; or in a special machine designed for the drilling of holes in that one piece of work. But, though the results may be identical, a method suitable for one class of job would generally be undesirable for another. In all large shops devoted to the production of specialties all methods are in use, and the choice is often one of the principal duties of the management.

Gauges,—used to check the degree of accuracy of finished work,—are made to exact even dimensions, or they are limit gauges, being of a definite amount, $\frac{1}{1000}''$, $\frac{1}{2000}''$, etc., above or below nominal dimensions, for the purpose of giving precise sizes in place of the slack and easy fits, or full and tight fits of the older practice. By the foregoing methods the greatest economies are effected in modern machine shops, and when necessary or desirable, the interchangeability of machined parts is secured without any after adjustments; for if a piece of work requires adjustment at the hands of the fitter, it is no longer interchangeable with other parts.

In the modern system the preparation of the jigs, templets, and gauges has created the tool room,—a department which is rapidly supplanting the old-time coarse methods of measurement, and dispensing with the necessity, inseparable therefrom, of mutual adjustment of parts, in which there was no strict adherence to absolute dimensions. The tool room saves the time once wasted in oscillation between the smithy and the grindstone, with the further advantage of securing uniformity in the shapes of tools, cutting angles, temper, etc. In the old days every man was a law unto himself, and this is true in some shops now; but in the best modern shops the individual is subordinated to the system.

In proportion to the substitution of gauges for rule and calipers does a machine shop deserve to be considered modern. The gauges are hardened and ground in the tool room, and stamped for their work, and stored there. Rings and plugs, horse-shoe, gap, and rod gauges dispense with movable calipers and rule, and save time, while ensuring the precise results which are at the basis of the modern interchangeable methods. A reamer will finish a hole within the thousandth or two-thousandth part of an inch, according to the limit allowed. A cutter in a box will turn within similar limits by means of Vee supports opposed to the tool; or, if the work is bored, and of no great length, by means of a pilot pin fitting the bored hole. The old function of the movable caliper is transferred to the maker of the box tools in the tool room, which, when once fitted, dispense with the need of checking the work as it proceeds, the only check which it receives being at the hands of the gauges subsequently.

From all this specialisation of machines, and the use of jigs, templets, and gauges, there follow, as a natural result, much division of tasks and separation of shops. The division of tasks is a truism which has been repeated so often that it may seem well-nigh unnecessary to refer to it. But it is too important to be passed by without brief comment, as it applies to engineers' machine shops. Here the cutting off, ending, and centering of bars should not be done by the lathe hand, but by a man or men kept specially for those tasks. A general lathe hand is not put on a capstan lathe, or on a drilling machine, nor is a driller put to operate a planing machine or a lathe. The common lathe hand is seldom entrusted with screw-cutting, and the skillful screw-



A TURRET HEAD BORING AND TURNING MACHINE, BUILT BY MESSRS. GEO. RICHARDS & CO., LTD., BROADHEATH, MANCHESTER, ENGLAND

cutting hand does little plain turning. Gear cutting is done less in the universal machines and more in those of special design by hands who perform no other tasks. In the modern shop the tools are ground by men who never use them, and the lining out by men who do no machining or fitting, while those who fit seldom carry out the final adjustments, assembling, and erection of complete mechanisms.

This minute division of labour is rendered most complete in the modern shop by an increasing separation of the departments. The value of this is now better understood than it was formerly. The custom which still exists with many firms of having one aggregate shop, in which machines of all classes are dumped down without discrimination, as the business of the works has increased, is ill suited for the most economical system

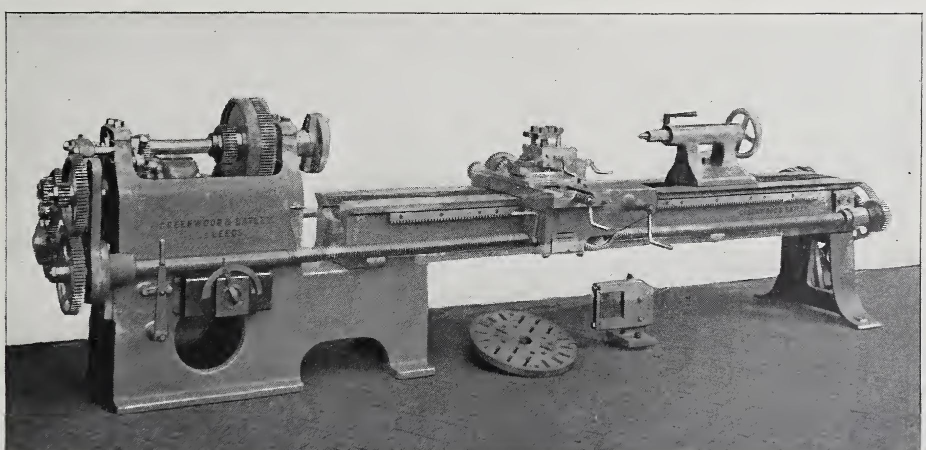
of production. As there is nothing in common between drillers and planers, between gear cutting hands and slotters, between the milling machine men and the minders of automatics, there is, therefore, an advantage in making a separation between them, if not always in distinct rooms, yet in separate floor areas and groups.

Large numbers of shops,—probably the greater part,—are built with a long bay on the ground floor which is occupied by heavy machines, covered by travellers, or served by walking cranes down the centre, and having galleries for light work running down the sides of the shop at a height of twenty or thirty feet above the floor level. This is an excellent arrangement, particularly in cities where land is valuable. Another method, not so good, but which is unavoidable when old firms cannot expand laterally, is to have floor above floor, the heavier work being done below and the lighter on the upper floors.

But, when practicable, the ideal arrangement for a machine shop is to have everything located on the ground, doing away with upper stories, and even galleries. The latter occasion some loss of time in transportation, and are not so readily overlooked. Having all work performed on the level, trolley tracks can be utilised for transportation, and vibration of machinery can be all absorbed on concrete foundations. Because of the cramped condition of things which prevents extension on ground areas in big cities, many wide-awake firms have gone to the outskirts, where they can spread out with extension of business.

No very hard-and-fast rule can be laid down in these matters, because the character of the work done in a given factory must have a vital bearing on arrangements. In the case of firms who do a large volume of a light class of work, galleries, and even two or three-storied buildings, are suitable enough. But as output increases in weight the laying out of all the shops on the ground level becomes more desirable, and in some instances even imperative.

Hoisting tackle in a machine shop consists chiefly of overhead travellers and of walking cranes for heavy work, and light jennys or swing cranes for small work. The preference of the writer would be for electric travellers, and, after those, for the cotton rope type. Square shaft and steam driven ones are ill suited to modern requirements. An objection to travellers of any kind is that the belting below interferes somewhat with their range of movement. There is not much in this objection if the shop is arranged with a



A NEW ELECTRICALLY DRIVEN SCREW-CUTTING LATHE, MADE BY MESSRS. GREENWOOD & BATLEY, LTD., LEEDS, ENGLAND

A PART OF THE WASH ROOM AT THE WORKS OF THE BROWN & SHARPE MFG. CO., PROVIDENCE, R. I., U. S. A.

clear run down, and clear of belting a good distance on each side of the centre.

The walking cranes, also termed single-rail cranes, driven by cotton ropes or electrically, are used to a considerable extent in several of the leading shops of Great Britain. It is handy to have cranes running down the centre of the shop and serving machines to right and left. But such cranes occupy space which would be better if not encroached upon, and they have no advantage over the travelling cranes.

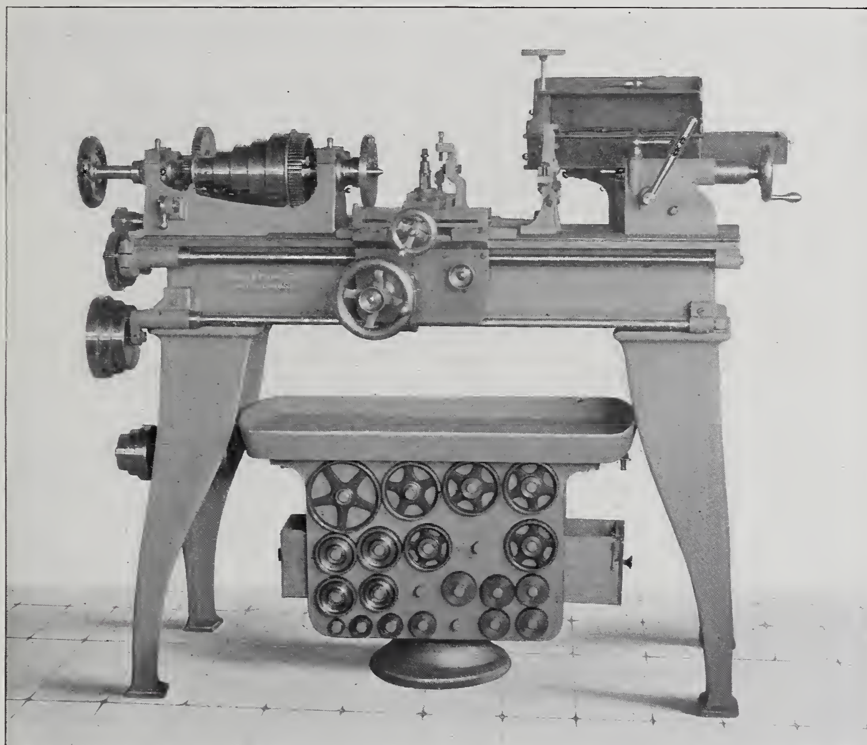
In the lighter departments of the machine shop a crane is generally unnecessary. If any be required, a light hoist of some one of the numerous types running on rails, or on a single rail overhead, is suitable. But if a clear gangway is left down the shop between machines, a trolley track in the centre will generally be sufficient to serve the machines and convey the light work, which can be lifted by a labourer. Cleanliness is now recognised as of more value in the machine shop than formerly. A dirty, littered shop breeds carelessness and slovenly methods of work. Some work must needs lie on the floor around machines, but not oil and dirt, nor small tools. In harmony with this growing ideal of cleanliness and order we find work and tool trays on the later machine-tools, cabinet legs, and cupboards, pigeon-holes for change wheels, oil trays with taps, etc.

Another matter which is beginning to be considered important in a machine shop is warmth. Naturally, the shop is a cold one, being less favoured in winter time than the smithy or foundry. In bitter weather, open "devils" burning coke, placed about the shop sometimes poison the men with sulphurous fumes. No firm which cares for its hands, or even for the economies which result from men working in comfort, should fail to lay down a proper heating

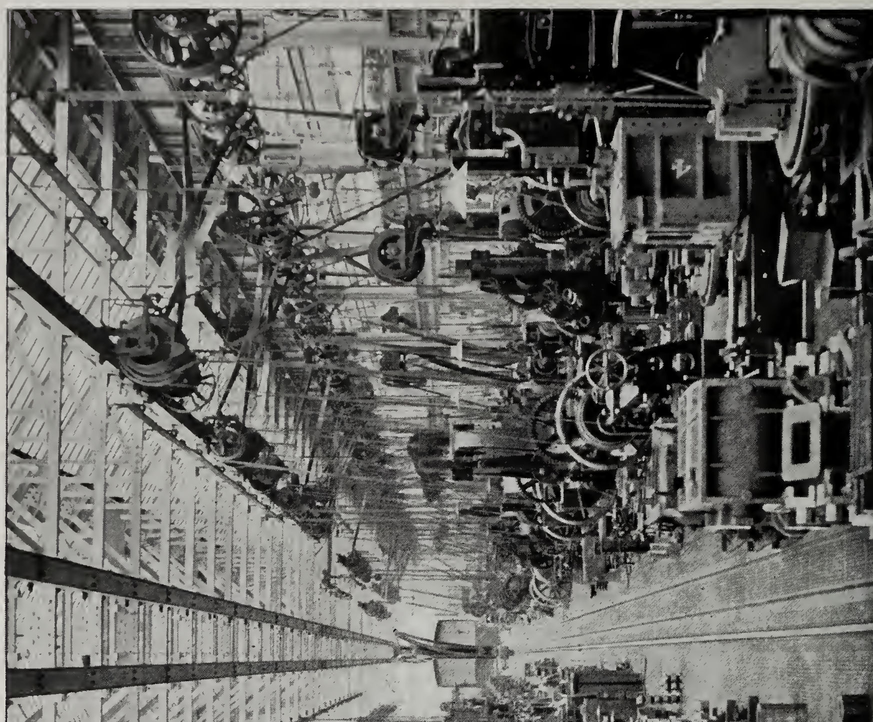
system. Neither should they neglect to provide a lavatory and allow a few minutes for washing before leaving work.

The finished stores for separate machined parts are indispensable in the modern shop. In the past they have been neglected too much. There are shops which, to use a shop phrase applied to them, are like a marine stores. Men are allowed to throw their work about on the floor and under the machines and benches in heaps, and the fitters come and take what they want, and no check is kept. The consequence is that some smaller pieces of work are lost, and have to be replaced, and then, by and bye, there is an unearthing of forgotten articles which probably go to the scrap heap.

In any shop the best arrangements adopted for stored work must be the result of long and ripe experience. The larger and heavier it is, and the fewer the number of separate parts, the less is the advantage which may be gained by making the different parts in quantity and putting them into stock. In a marine engine works, for example, nothing of importance can be done in this direction in a British locomotive works not very much beyond the smaller rods and pins, and some of the brass fittings; in a manufacturing machine tool shop everything except the heaviest parts of the largest machines can be so made and stocked. So, too, can the small parts of pumps, of standard engines, and much electrical machinery. The smaller details will be made and kept in greater numbers than those of medium dimensions, or than completed sections. In proportion to the complexity of a section the numbers stored will generally be lessened. It may be interesting



A TOOL MAKER'S LATHE, MADE BY THE PRATT & WHITNEY CO, HARTFORD, CONN., U. S. A.



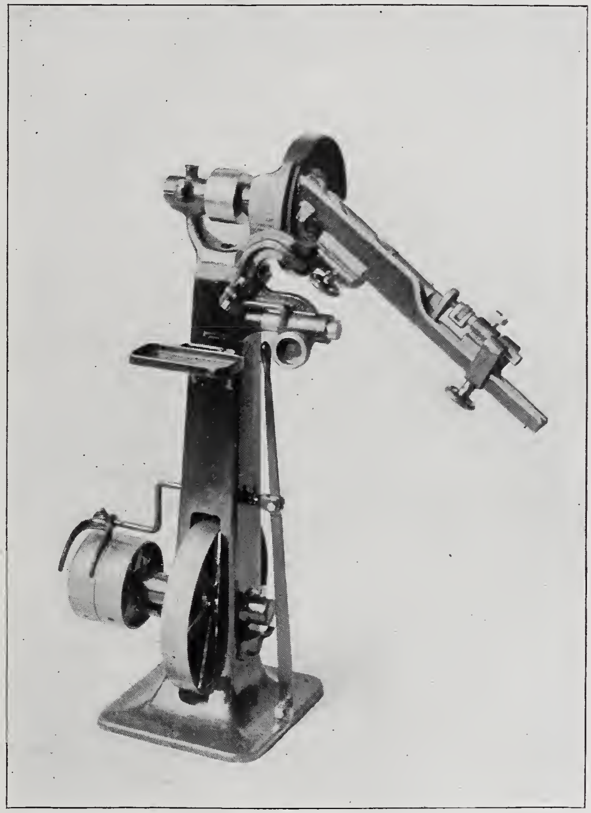
THE MACHINE SHOP OF THE LANCASHIRE & YORKSHIRE RAILWAY, HARWICH, ENGLAND

here to refer to the illustrations on pages 394 and 397.

Stores, well arranged in themselves, are often defective in lighting arrangements. This is a fault common to many of the older shops. When work is stored in pigeon-holes, and on shelves one above another, the need of abundant light is apparent. It is wasteful of time, and risky, too, when, in broad daylight, the storekeeper has to lcok up required parts by the aid of a candle or lamp.

Looking, now, towards the future, the electric driving of machine tools, yet in its infancy, attracts attention. Greater progress has been made in this matter in the United States than in Great Britain. Up to the present time it has remained pretty much in the experimental stage. There are, however, several large firms in which the method has been adopted with advantage.

In this, as in so many other matters relating to workshop practice, no hard-and-fast rules can be laid down, because of the varying conditions which exist in different manufactories. It is generally agreed that the system of shafting and power transmission in factories is a very imperfect one, expensive, in the first place, and costly to maintain, absorbing an immense deal of power, blocking the light, obstructing the hoisting machinery, producing and accumulating dirt, besides being, as a system, inelastic in character. Electric transmission is not open to either of these objections, except the first-named,—that of first cost, — and it is, therefore, a system which should be carefully studied by those who contemplate either laying down new shops or effecting important extensions in old ones. The problems which arise in the course of the working out of the system are numerous, involving expert knowledge of the types of motors and apparatus employed. Opinions vary widely in respect of these details, and a period of trial and error may be expected to elapse before any general consensus of opinion will be possible, such as would induce firms to commit themselves altogether to the substitution of electric driving for shaft transmission.


A DRILL GRINDER MADE BY THE FULLER MFG. CO., KALAMAZOO, MICH., U. S. A.

That electric driving is eminently adaptable to the requirements of the modern factory is evident from the fact that it is suitable alike for driving heavy armour-plate planing machines and very light machine-tools, and that it drives also the highest powered travellers, and lights the machines electrically driven.

In reference to the driving of single

BRASS FINISHING SHOP AT THE BALDWIN LOCOMOTIVE WORKS

machines, ideas are more rational than formerly, since it is becoming understood that to take a machine of ordinary type and attach a motor to drive the belt,—though an easy way to cut the Gordian knot,—is not good engineering. The belt must be knocked out, and the drive be direct. In this respect the evolution of the electrically driven machine is paralleled by the evolution of the electric traveller from the cotton rope basis to the all-electric type.

The paramount importance of modern machinery in an engineer's shop is so immensely greater to-day than it was a few years since, and developments are so rapid, that it would not be unsafe to predict that many of the new and recent machines now in use will be superannuated within a decade or so. Ten years are not a long period, but recent experience, and the recent drift of shop practice, serve to show that they more than cover the economical working life of some machines. Under such conditions, obviously, the most judicious course to adopt is to purchase the best machinery available at the present time and utilise it to the utmost. Of a good machine it may be said, in a practical sense, that it never wears out. Then it is better to wear it well while it remains in service.

Some firms take pride in having retained such and such machines in constant service for a generation or more, and would not part with such old servants on any account. In most cases this is a mistaken policy to which there can be few exceptions. Some of the best of the old machines, say, of thirty years ago, may be capable of doing as good work as those of modern build; but often the work is now more rapidly done on machines of other types, and by different methods.

THE PRINCIPLES OF REFRIGERATION

By George Richmond, M. E.

IF we approach the subject of refrigeration as absolute novices, the first thing that strikes us in observing an ice factory from the outside is the fact that coal is seen to go in and ice to come out. If we ask for an explanation of this singular transformation, we may be told that the ammonia does it; at another place we should be told that sulphur dioxide does it; at a third, that carbonic acid does it; and at a fourth, that air does it. This is rather confusing, but we notice that in all cases the coal is present,—and conclude that this is a more important factor in the process than any of the substances named. As to the proportion between the coal and the ice, we find that this varies greatly, but that eight tons of ice for a ton of coal is considered a very good average, while twelve or fourteen tons are occasionally obtained.

Pursuing our inquiries a little further, we come to a plant where no coal is used. This gives us a clue as to the particular property of coal that lends itself to ice making. For where no coal is used, we find that there is a water-wheel or some other source of power. Retracing our steps and looking a little more closely into the matter, we find that in every case work is done, and this explains the part the coal plays in the transaction.

The mechanism is usually a steam engine and a gas compressor, and the problem is to produce the most refrigeration with the least amount of work, and hence with the least amount of coal. We are familiar with the problem of producing the greatest amount of work from a given quantity of coal; the corresponding problem of producing the largest amount of refrigeration from the smallest amount of work is so similar in its details and principle, that the nature of the relationship should be understood to enable us to apply whatever knowledge we may have of the steam engine to the refrigerating machine.

At this point it may be of interest to present the simple diagram given in Fig. 1. It represents a most primitive and simple means of raising water from a well by utilising a head of water. Hydraulic analogies seem to assist the mind, probably because the notions are so familiar that we see at once the correctness of deductions based on them. This is found to be the case in electricity, and is equally so in heat relations. Whenever we have knotty problems in refrigeration, we can come back to our

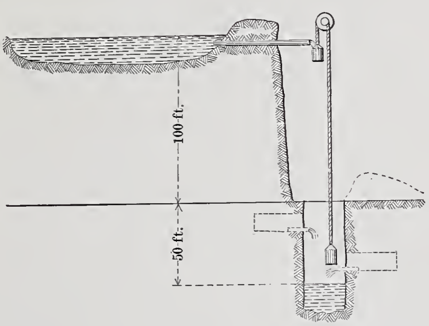


FIG. 1

diagram and solve them with ease and confidence in terms and quantities with which we are perfectly familiar.

The descending bucket which is filled from the overflow of the lake is a modest but faithful representative of the steam engine. We utilise 100 feet of fall, and every pound of water will give

us 100 foot-pounds of work to be applied to any purpose we like,—in this case to the raising of two pounds of water from a depth of 50 feet.

The lake may be situated 1000 feet above sea level, and every pound of water in it has a capacity of doing work or a possible energy of 1000 foot-pounds. We get only 100 foot-pounds of work because the base line is supposed to be drawn at the lowest level at which the water will flow away from the apparatus; 100 foot-pounds are the available energy, and are 10 per cent. of the total energy. It may be well to recall the corresponding fact that we cannot utilise the total energy of the coal. In the very best engine we get less than 20 per cent., but 7 or 8 per cent. is a fair average for a single-cylinder engine.

The more efficient engines differ from the less efficient in several particulars. We might at first be inclined to say that the most essential difference lies in the steam pressure used, but if we follow this out we shall find that the efficiency is not proportional to the pressure. It was Carnot who first pointed out that the significant factor is the temperature, and that the efficiency is proportional to the range of temperature, that is, to the difference between the temperature of the steam in the boiler and that in the condenser.

To utilise all the heat, we should have to draw our base line at absolute zero. Where is absolute zero, and how was it discovered? Air at 32° Fahr. shrinks $\frac{1}{492}$ for each degree of cooling; hence it could shrink 492° or 460° below 0 Fahr. There are other means of determining it, and it suffices to know that our base line, when we discharge heat at 100° Fahr., is really about 560° above absolute zero. In the case of the waterfall a means of getting rid of the water when used is equally as important as the supply. No one would listen to a man who proposed, under the given circumstances, to put in a water motor which would yield more than 100 foot-pounds of work per pound of water used; but the expectation of getting a greater percentage of work out of heat than is represented by the ratio of the actual drop to the possible drop to absolute zero still survives. Many other analogies might be traced. Full value of the water power is obtained only when all the water enters the bucket at the highest point. Full value of heat energy is obtained only when all the heat is supplied at the same temperature, or more correctly at the highest temperature at which it is available in a given case. Heat may be received at different temperatures, but the essential condition of full efficiency is that there may be no uncompensated drop of temperature in the cycle itself. If the bucket leaks (even if the water is caught below and returned to the bucket on its way down) a part of the effect is lost. All heat receptacles leak; when steam enters the cylinder, the heat leaks into the walls, and although all should come back to the steam during expansion, its effect is diminished, because it comes into play at a lower temperature.

Seeing that these analogies hold for the heat engine, we may apply them with confidence to the refrigerating machine as represented by the well. Refrigeration is really the removal of heat from a low temperature level to a higher level and discharging it there. The amount of work for a given amount of refrigeration depends on the height of the lift, or the difference in temperature between the refrigerator (the bottom of the well) and the condenser (level of discharge).

This fact disposes, once for all, of the significance of the agent,—whether ammonia or carbonic acid, or other medium. If either were used in the best possible manner, the result would be the same; as a matter of fact, however, they are not and cannot conveniently be so used, and we shall find that there is a wide difference in the amount of loss caused by the compromise actually made when different agents are used. We do not have to rely on theory alone for demonstration of this relationship between the range of temperature and the amount of work required.

Some experiments made with a refrigerating plant gave the results in the

table below. The condenser (discharge) temperature was the same in each case, and the numbers opposite the corresponding temperatures give the number of thermal units removed per horsepower of work expended.

Refrigeration per horse-power. Condenser 70°.

Refrigerator	37°	21,703	Thermal units removed per H. P.
"	22.9°	16,026	
"	8.7°	10,841	
"	5.9°	8,531	

From this we see that at 8.7° the cooling effect is only one-half of that produced by the same work at 37°, and that it diminishes very rapidly as the refrigerator temperature decreases. By drawing a curve through the points representing the cooling per unit of work, (see Fig. 2,) we can estimat ethe amount for intermediate temperatures.

Of course, we are compelled to run the machine so as to produce the lowest temperature actually required; nevertheless, a proper recognition of the facts now in question would save thousands of tons of coal every year. It is still a common occurrence to meet with an engineer who boasts that the excellence of his machine and the skill of his management are shown by the fact that he is running with a temperature approaching zero, when about 25° is all he requires. He points with pride to the ease with which his engine works with the low back pressure he is getting.

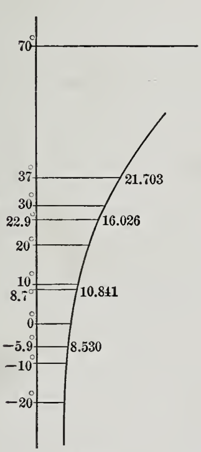


FIG. 2

The facts are, of course, that his machine is of greater capacity than his present requirements call for, and that he is burning about twice as much coal as he needs. This error in judgment is most frequent when brine circulation is used, and the excuse is made that a reserve is thus obtained in his brine tank. Admitting the acknowledged importance of providing against accident, it is an open question whether it would not be cheaper to duplicate the machinery and run on correct principles. In any case, if a brine tank is used, the storage capacity could be increased ten-fold without lowering the temperature more than a few degrees, by placing in the brine tank a series of vessels containing such a mixture of water and salt that it would freeze at the lowest temperature desired.

When this temperature is reached, the extra power of the machine would be employed in freezing these up; and should the machine stop, they would form an immense reserve which would keep at about the same temperature until all the salt-water ice-cans were thawed out. This may be termed an accumulator system by analogy with the storage battery. Thus it will be found that in most cases any desired result may be obtained without unduly sacrificing the efficiency of the machine if attention be paid to the principles involved.

Another case in which the application of this elementary principle would effect a great saving in coal is that in which most of the rooms have to be kept at moderate temperature while one or two only must have a very much lower temperature. This often occurs in cold storage warehouses, where, perhaps, only 10 per cent. of the space is required to be kept at a very low temperature. There is, then, a loss in cooling the moderate temperature rooms. This is illustrated in the sketch, Fig. 1. If we suppose that the water-raising apparatus is adapted to draw water from the bottom of the well, and that 90 per cent. of the water flows into it from a higher level, it seems absurd to let the water first fall from a higher level and then draw it up, but this is precisely what we do in refrigeration under the circumstances supposed.

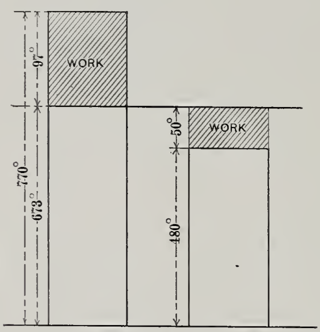
The remedy, of course, is to adapt the machine to the higher temperature room and use a special machine for the lower temperature rooms. This auxiliary machine might either lift the heat from the lowest temperature to the top, or it might lift it to the level of the moderate temperature room. As an

illustration, suppose 90,000 thermal units have to be removed at 23° and 10,000 at 9°! If the machine is adjusted to suit the lower temperature, 10 horse-power is required, but if two machines are used, then:—

To raise	90,000	from 23°	requires	5.6 horse-power.
"	10,000	" 9°	"	1.0 " "
Total				6.6 horse-power.

In other words, 34 per cent. of the coal would be saved.

Moreover, in selecting a machine it should be ascertained that this principle has been conformed to. One favourite way of cheapening a plant is to stint the cooling surface. This is a very costly



FIGS. 3 AND 4

economy for the purchaser. If the condenser surface is too small, the heat is raised to a higher temperature level than necessary in order that it may flow away. If the refrigerator surface is too small, the heat is raised from a lower temperature level than is absolutely necessary. Here, again, we can point to experimental results to confirm the theory. A certain plant was run first with a given surface in the refrigerator and then with the double of this surface. The brine was kept at the same temperature in each case, but, of course, in the case of the smaller amount of surface, the actual temperature within the system was lower than in the case of greater surface. The results were:—

With single surface....7015 T. U. per horse-power.
With double surface...7770 " " " "

or about 11 per cent. more refrigeration per horse-power was effected with the additional surface.

In this instance the increase was twenty thermal units per hour per extra square foot of surface. This amounts in ten years to about six tons of refrigeration. Doubling was an excessive addition; if the extra pipe surface had been more moderate, then each extra foot would have represented more than six tons. But the loss of six tons of refrigeration is a pretty high price for a square foot of surface.

There are two systems, in one of which the agent (usually ammonia) is circulated directly in the rooms to be cooled, and another in which brine is first cooled by the ammonia and afterward circulated, and our hydraulic analogy points clearly to the exact significance of the two methods. We can drain a space only by taking the water from a little below its level; so that when ammonia is circulated, its temperature (which is the temperature really governing the efficiency of the machine) must be less than the temperature of the room or of the brine it cools.

In direct expansion, it is one step lower than the temperature of the room; in brine circulation, it is one step below the temperature of the brine, and, therefore, two steps below that of the room. Now, we have seen the effect of pumping up the heat from a lower level than is absolutely necessary, so that whatever practical reasons may or may not obtain in special cases, the two-step process is wrong in principle, since it costs more coal per unit of refrigeration than the single step.

We may now state the principle thus investigated in terms of heat and temperature. That portion of a unit of heat which can be converted into work may be termed the available energy, or its dynamic value. If a quantity of heat be represented by a rectangle of which the height is equal (on any convenient scale) to the constant temperature (absolute) at which it is taken in, and another line drawn at the lowest constant temperature at which it can be rejected or carried away, then the part cut off represents the whole of the heat which can be converted into work.

If steam be taken at 770°, correspond-

ing to about sixty-five pounds pressure, and rejected at 673°, then the maximum percentage that can be converted into work is $\frac{97}{770} = 13$ per cent. (see Fig. 3). A good steam engine would actually give about 50 or 60 per cent. of this.

If a quantity of heat to be removed at constant temperature be represented by a rectangle whose height is the absolute temperature from which it is to be taken, then if a horizontal line be drawn at the lowest temperature at which it can be discharged and the rectangle completed, the rectangle thus formed is the smallest amount of work (in heat units) required to effect the removal.

Suppose we wish to raise a thermal unit from 20° (absolute 480) to 70° (absolute 530), assumed to be the lowest temperature at which we can get rid of it, then $\frac{50}{480}$ T. U. is the least amount of work expressed in heat units. Now, one ton of refrigeration per day is equivalent to raising about 200 thermal units per minute, so that the work per ton would be $\frac{50 \times 200}{480} = 21$ T. U. But one horse-power is equivalent to about 43 T. U.* per minute, so that $\frac{21}{43}$ of a horse-power would be required. A good refrigerating machine would use about twice as much power. Notice that the diagrams Figs. 3 and 4 represent an exact analogy to the water fall and the well.

Coming now to the actual machinery used, the scheme of the complete refrigerating apparatus is that shown in the diagram Fig. 5. The steam engine is not shown, as it is obviously immaterial whence the work is derived. The shaft when revolved operates the-compressor piston, draws in the agent, or heat conveyor, from the refrigerator, compresses it and forces it into the cooler. From this it passes into the expansion cylinder, where it expands against the piston, doing work, and thus assisting the engine in driving the compressor. The agent is cooled by doing work, since the work is done at the expense of its heat.

It now passes into the refrigerator, where it takes up heat, and the cycle is completed. It is seen that the agent is a mere heat carrier, of which the bucket in our well was the type. All the heat

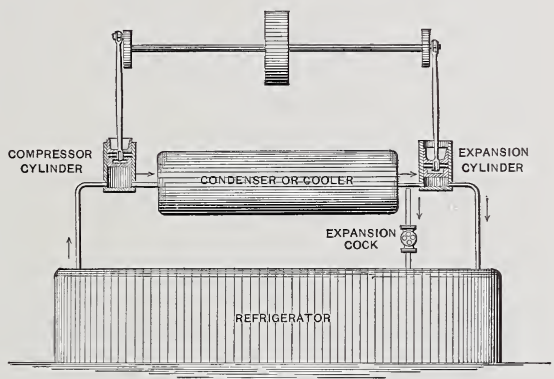


FIG. 5

it carries from the refrigerator is deposited in the cooler, or condenser, from which it is finally carried away by the water flowing through the latter. When the complete plan, comprising the compressor and expansion cylinder, is used, all agents are theoretically equally good. Practically the question of size of cylinders and moving parts required would be very important. When air is the agent used to convey the heat, the expansion cylinder cannot be omitted, for air, considered as a perfect gas, cools itself only by doing outside mechanical work. The modern methods of liquefying air are based on the fact that it is not a perfect gas, and becomes less and less perfect as the temperature is reduced.

When the agent is a liquefiable gas, the expansion cylinder may be omitted. There will, in this case, be a loss of refrigerating effect, but not a total loss, as in the case of air. The reason for this

* Wnen work is converted into heat, 778 foot-pounds are required to raise a pound of water 1° Fahr., or furnish 1 thermal unit. A horse-power expressed in thermal units is $\frac{33,000}{778} = 42.4$ T. U. per minute.

is that when a substance changes its state from liquid to gas, internal molecular work is done, as well as external work.

We may follow the cycle with a liquefiable gas. It comes to the compressor as a gas, and is compressed to such a pressure that it will liquefy at the temperature of the condenser. To effect this the molecules must part with much of their heat energy, which passes into the water and away with it. The agent enters the expansion cylinder as a liquid, and the work is done at the expense of the heat in the liquid. Long before the whole of the liquid is vapourised its temperature is reduced to that of the refrigerator. It then passes into the refrigerator as a mixture of vapour and liquid.

The further vapourisation is effected at the expense of the heat in the refrigerator. In other words, the agent absorbs heat in the refrigerator by changing to a gas, and carries it through the compressor to the condenser. If we leave off the expansion cylinder and pass the liquid direct into the refrigerator through an expansion cock,—which is the universal practice when a liquefiable agent is used,—we have a double loss.

First.—The liquid enters the refrigerator at the temperature of the condenser, and has to be cooled down to the refrigerator temperature before it can do any useful work.

Second.—We lose work which was done in the expansion cylinder, and the engine has to do so much more work. This double loss is more correctly expressed as follows:—The work which the agent would have done in the expansion cylinder it actually performs in the refrigerator in imparting to itself a certain velocity. The act of bringing the agent to rest converts its energy of motion into heat, so that when an expansion cock is used the work is increased and the refrigeration diminished by exactly equivalent amounts.

It may be noticed, in passing, that the agent is frequently allowed to pass into the refrigerator at a higher temperature than is necessary. It is often heated up to the temperature of a hot engine room. A material saving would be effected by cooling the liquid just before entering the refrigerator to the temperature of the coldest water available.

It is evident that leaving off the expansion cylinder will affect most unfavourably those agents in which the heat of the liquid is large in proportion to the latent heat, for latent heat is the name under which the molecular work involved in changing of state is known. For this reason different agents have very different efficiencies in practice.

For example, in raising heat from 4° to 62°, using ammonia, sulphur dioxide and carbonic acid, the loss in effect by reason of the omission of the expansion cylinder is, respectively:

Ammonia	6.3 per cent.
Sulphur dioxide	7.3 "
Carbonic acid	34.6 "

A few words, in closing, must be given to the absorption machine. This is very interesting, from the fact that though coal is used, there is no visible steam engine. A solution of ammonia in water is heated in a still, usually by means of steam coils, until the ammonia is driven off into the condenser under the pressure necessary to liquefy it. The gas resulting from the vapourisation of the ammonia is absorbed by pure water in the absorber, and the solution thus formed is transferred to the still to be again treated. The pump to effect this transfer is the only visible mechanism in motion. The claim that the insignificant amount of power required for operating this pump represents the total energy expended is, of course, presented only to very credulous and ignorant people; but the substitution of a chemical process, brought about by direct application of heat, for the work done by a steam engine seems to present considerable difficulty, even to well-informed people. Some writers on the ice machine have been hopelessly befogged by this circumstance. One asserts that since there is no steam engine all the heat should be available, and gives the possible production of the absorption machine at ten times that of the compression machine.

But if what we have considered as fundamental principles are correct, we we shall not hesitate to say:—" We cannot ' see the wheels go round,' but we see heat coming in at a high temperature and going away at a lower temperature, in consequence of which certain work is done." It is, therefore, a veritable heat engine, however it may be disguised, and you never can utilise all the heat in the coal unless you drop down to absolute zero. And when we are told that a theory calls for keeping the absorber as hot as possible, we shake our heads and say:—" Since you discharge heat at the absorber, it never can be an advantage to discharge heat above the lowest temperature level obtainable, any more than it can be an advantage to discharge water at a higher level than necessary. If it is the discharge from the motor, you rob it. If it is the discharge from the pump, you overload it. We cannot follow your intricate calculations, but these are fundamental principles on which we take our stand."

We may, by reference to our simple illustration of the water buckets, find a definition which will cover both the compression and the absorption systems. Refrigeration is a phenomenon of equivalent transfer of heat in which the raising of a quantity of heat from a lower to the mean temperature is compensated by the falling of another quantity of heat from a higher to the mean temperature. In the diagram the raising of a quantity of water from the well is compensated by the falling of another quantity of water from the lake. The transfer is equivalent when the work done by the falling water is equal to the work done to raise the other water. In the case of heat the transfer is equivalent when it is accompanied by an equivalent transformation of heat, that is (referring to Figs. 3 and 4), when the shaded areas representing, respectively, the heat transformed into work and the work transformed into heat are equal. In the case of the compression system this double transformation of heat into work in the steam engine and work into heat in the compressor is easily traced. We are just as sure that the same principle may hold good in the absorption system as would be in the case of the hydraulic illustration, supposing the mechanism to be concealed or disguised in any manner. If this be true, it is an interesting corollary that in chemical transformations, brought about by the agency of heat, a knowledge of the quantities only of heat involved will not usually afford an adequate explanation of the phenomena.

As a matter of fact, with a given range of temperature, the mechanism of the absorption machine may be more or less efficient than the steam engine in converting into refrigeration work the available energy due to that particular range of temperature. The compression machine, however, enjoys the advantage of having its power cycle perfectly distinct from its refrigeration cycle, which is not the case with the absorption machine as usually operated.

It has been contended that a compression machine can always be designed to give greater efficiency than any absorption machine, simply by enlarging the range of temperature of the steam engine. It is obvious, however, that if the absorption machine is a true heat engine, there is no inherent limitation of the temperature range it can utilise.

SCIENTIFIC SHARPSHOOTING

By Horace Kephart

THE Napoleonic maxim that "fire is everything" is truer in these days of smokeless powder and long-range weapons than ever before. An expert shot is no longer blinded by his comrades' smoke; nor is his position revealed by his own smoke when firing from cover. Ten sharpshooters nowadays are worth more than fifty bunglers with the rifle.

But the word sharpshooter is often misapplied. During the war between the United States and Spain, the writer remembers reading a correspondent's account of how a Spanish "sharpshooter," hidden in a tree, fired three deliberate shots at him, within fifty yards range, and missed every time. To the reporter and to the general public this clumsy guerilla was a sharpshooter, merely because he was up a tree and shooting "on his own hook."

Properly speaking, a sharpshooter is a man of uncommon skill with the rifle. He never fires at random, but picks out some one object, aims with deliberate accuracy, and shoots to kill. Not one shot in 500 that are fired by ordinary troops in battle does any execution, but a sharpshooter who missed three times out of five would be disgusted. The instant that he draws trigger he knows just where his bullet has gone. There is no guesswork about it; no trusting in luck to hit the mark.

Such skill is not a natural endowment. It is the fruit of long practice and study. One may be blessed by nature with keen eyes and steady nerves, but these qualities of themselves will not make him a good shot. On the other hand, nervousness or near-sightedness, though they handicap one at the start, do not bar one from becoming a good marksman. Skill in rifle shooting comes, first, from thorough knowledge of what arms and ammunition can do, and, equally important, what they cannot do; secondly, from accurate judgment of distance and atmospheric conditions; thirdly, from true aim, and the ability to draw trigger at precisely the right instant, without the slightest jerk or quiver. All of these accomplishments can be cultivated by men of average physique and intelligence, if they work hard, stick to it, and put brains into their practice.

It is the purpose of this article to show that military sharpshooting is in a rudimentary stage, and to offer some suggestions for its improvement. The standard of marksmanship in modern armies is higher than formerly, but it is still entirely too low. It is much lower than that of civilian riflemen. Take, for example, off-hand shooting, by which the writer means shooting without artificial rest, either from the standing or kneeling position. This is the most important of all fire discipline, because most of the shooting in actual battle must be done off-hand, at least by the attacking party. It is also the most difficult kind of rifle practice.

There are few soldiers in any regular army, to say nothing of the militia, who, with the service rifle, can be relied upon to place most of their shots in a 12-inch circle at 200 yards, off-hand. A large majority of troops cannot do nearly so well. But go to the range of some civilian rifle club, whose members practice rifle shooting for pastime, and note the difference! None of these men consider that they shoot well unless they can "call their shots," which means that the shooter can announce almost exactly where his bullet has hit before the marker at the target has signalled the result.

At prize shooting, where experts are

gathered, you may see one of them call his shots repeatedly within two inches of where they actually struck, 200 yards away. In other words, he can detect a movement of a hundreth of an inch at the muzzle of his rifle at the instant of discharge. This, bear in mind, is with the unaided eye, the marksman standing erect and shooting off-hand. A run of fifty consecutive hits on a 12-inch bull's-eye at 200 yards, off-hand, is not uncommon. Such nail-driving accuracy of fire counts for as much on the hunting-field or battle-field as on the range. Bullets are no respecters of targets. It is all the same to them, be it paper, deer, or man.

Now why is the marksmanship of regular troops inferior to that of civilian riflemen? The trouble lies in their training and armament. In the first place, a soldier has little stimulus to excell in marksmanship. The amount of ammunition allowed him for target practice is entirely too small. If he wants more, he must pay for it out of a private's pittance. Suppose that he does so, and works hard to qualify as sharpshooter; how does the government reward him? The best shot in a regiment does not receive one penny more pay than his blundering comrade who shuts both eyes and flinches when he draws trigger.

So it is not to be wondered at that a considerable proportion of soldiers regard target practice as they do any other military duty,—it is merely so much work to be done. Again, a soldier who aspires to become a good shot is handicapped by not being allowed any discretion in selecting or fitting-up his weapon. Hard-and-fast rules bind him to use sights and trigger-pull that are not adapted to accurate shooting. Tall men and short men alike must use gunstocks of the same length and drop, which is much as though they had to wear trousers of the same length and girth. There is little incentive for the soldier to experiment and invent improvements, for, most likely, they would not be tolerated. Officers do not use the same weapons as privates, and are seldom skillful enough with the infantry arm to see any need of improving it. Indeed, it would be interesting to know whether the staff officers who decide upon armaments were ever themselves good shots. One cannot choose judiciously a tool that he cannot handle, nor teach what he does not know.

But with the civilian rifleman it is different. His shooting is a pastime, a passion. He puts energy and brains into it. By reloading his own ammunition he cuts down its cost so that he can afford to practice to his heart's content. He toils and studies over the instruments of his sport with the zeal of a hobby-rider, testing, testing, testing, comparing notes with his comrades, keeping abreast of the latest inventions, and comparing weekly his own scores with those made by experts throughout the world. He is bound by no precedent. Being his own ordnance board, he can adapt the tool with which he works to his own personal equation, until it becomes a part of him, as horse and man are one when both are in fettle for a race. This counts in rifle shooting as much as in any art or handicraft.

Now it is quite true that the rifles and ammunition generally used by civilian target shooters are not practical weapons for field use. But it is none the less true that a rifle can be so built and sighted as to be thoroughly serviceable and at the same time very accurate. The present infantry weapon is not well designed for sharpshooting. Its barrel is too thin and springy for accurate shooting, especially from rest, and it expands unevenly from over-heating. High-pressure smokeless powder heats a rifle barrel very rapidly, and, then, the bands that clamp the useless forearm to the barrel seriously interfere with its shooting qualities. The barrel is also too light for steady holding, off-hand. The trigger-pull is entirely too hard. Nobody who is himself a good shot would choose a six-pound trigger-pull for any imaginable work with the rifle. The sights are inaccurate, and they blur. Fine shooting is sometimes done with them on the target range, under selected conditions, but it is done by jockeying. The sights

are blackened, lines and dots are painted on them, and other means are adopted to help to greater accuracy. All this is as unpractical as a civilian target shooter's equipment.

If the sharpshooter is required to use regular infantry ammunition, his rifle should differ from a common musket in the following particulars:—Its barrel should be thick throughout, tapering very slowly toward the muzzle. On a telescope-sighted gun it need not be over 24 inches long. This restricted length, together with the amount of metal in the barrel, would give it stiffness, would keep it from excessive heating, would neutralise recoil, and would enable the man to hold steadily when shooting from hip-rest, which is the steadiest of all off-hand positions, and as practical in the field as on the range. If the rifle is a repeater, it should eject from the side or bottom, the frame being solid on top, so that the bolt would not interfere with the telescope. The trigger should be either a reliable "set" or a "drag" with light let-off.

A 10 or 12-inch telescope, of ⅞-inch diameter, with a short draw-tube for the eye-piece, closing up flush with the breech, should be rigidly mounted on top of the breech end of the barrel. The draw-tube is essential, for there should be no stick-out in the rear to catch in bridle reins or brush when the telescope is not in use. The main tube should be very strong. It should have no adjustment for elevation or windage, but should be fixed permanently to the barrel by screwing or locking it fast after adjustment, or even by brazing or soldering it to a rib, as double barrels are brazed together. All the parts should be as firm as human ingenuity and good workmanship can make them, for once a telescope is knocked out of adjustment it is useless. The magnifying power should not exceed four diameters, giving, with such a tube, a field of vision of at least 35 feet diameter at 100 yards, and 350 feet at 1000 yards, with strong illumination.

It is a mistake to use high powers in a rifle telescope. They restrict the field of vision, lessen the illumination, and magnify errors of holding. So far as aiming is concerned, a power of four diameters draws a man 1000 yards distant to within 250 yards of the shooter, and this is close enough for murderous accuracy. The cross-hairs should be of copper wire, rather coarse, so as to be clearly seen in bad light. The horizontal wire should be adjustable for elevation. The vertical wire should have "spots" for, approximately, 200, 500, 800, 1000, and 1200 yards, the exact value of each spot being determined by every man for his own gun, by actual firing. These spots would be used in quick firing, and would serve as indicators whereby the horizontal wire could be set for intermediate distances when there was time for deliberate adjustment. The field of vision of such a telescope would suffice for ranges up to 1500 yards, as the rise of the American Krag-Jorgensen bullet, for example, when the gun is sighted for 1500 yards is 93½ feet at, approximately, 900 yards. At the latter distance the field of vision of such a telescope would be over 315 feet in diameter. A deflecting prism could be used for ranges beyond 1500 yards, but it would be of doubtful value, as aimed fire beyond this range with a 0.30 calibre cartridge would be useless, and the sharpshooter would be expected to crawl within half that distance of the enemy. Very low open sights on top of the main tube of the telescope would be accurate enough for snap shooting inside of 50 yards, beyond which the telescope would have ample field.

Deadly aim could be taken with such a sight at a man nearly a mile away. There would be no blur, the target and cross-hairs being always in focus at all ranges. Changes of light would make little or no difference. Mirage would be eliminated. Good aim could be taken at dawn or twilight, and into dark thickets where the unaided eye was powerless. Men could be distinguished from stumps and stones. Officers could be picked out by their actions, even though wearing no insignia. Perhaps the greatest advantage of all would be that allowance for distance

could be made instantly, by simply holding higher or lower on the scale. There would be no guess-work about it, as in drawing fine or coarse bead with open sights; no lowering the rifle and fumbling with a sliding scale when every moment was precious; no over-shooting at an advancing enemy from forgetting to lower the rear sight.

A word as to the selection and training of sharpshooters. If it be not desired to recognise them as a special arm of the service, but to scatter them among the various commands, so many to a company, then from the best twenty shots in a hundred, with service rifle, select the most intelligent ten. The writer means those who are most trustworthy when acting on their own initiative. They must be men of nerve, but this is ensured both by the qualities that have made them expert shots and by their consciousness of superior skill. There is no better stiffener in the hour of battle than the calm knowledge that you can shoot straighter than the enemy.

Give them rifles built and sighted as described. Relieve them of petty duties. Give them at least corporal's pay, and a badge of merit. These distinctions, so far from exciting jealousy in the ranks, would make every man ambitious to win similar laurels, and thus would improve the marksmanship of the entire force. Allow your sharpshooters plenty of ammunition for practice. Turn them over to an expert, and have him put them through a hard course of training in rest shooting at long range, deliberate off-hand shooting at moderate range, and snap shooting at close quarters. Their long-range practice should not be from the absurd prone and back positions, which can seldom be used save on a cropped lawn or a desert, but from trenches and extemporised rests, such as would be used in actual battle. Train them thoroughly in estimating distances over different kinds of country, in trailing, in scouting, and in utilising cover. Teach them to scatter, every man for himself, scout over a large area, and re-assemble at a given point at a given time. Teach them to stalk an enemy as a hunter stalks game. Make them realise that needless exposure, reckless advance in the open, or mere bull-dog tenacity without definite object, are not virtues, but military crimes. Reward them for discretion as much as for valour. Allow them reasonable initiative. Consult their opinions. Make them feel that some of the burden of generalship rests upon them.

If practicable, give these men good mounts. Have them train their horses as the American Indians trained theirs, to lie still at command, and all that. On the march, use these sharpshooters as scouts. In battle, use them as skirmishers. Let them advance as far as there is cover for their horses, then, dismounting, and leaving behind all impediments save rifle, ammunition, canteen, tobacco, and a little hardtack, let them crawl within at least 800 yards of the enemy. There are few kinds of ground on which men skilled in " snaking " could not do this without being detected. Then, lying concealed even from the scrutiny of field-glasses, let them pick off officers and artillerymen. Using smokeless powder, their positions would not be revealed. Scattered, as they would be, at wide intervals and irregularly, neither shrapnel, case, nor machine guns would seriously affect them. With telescope sights they could generally see where their bullets struck, and this would give them the exact range. Twenty such men within 800 yards of a field battery could put it out of action in ten minutes. With horses in their rear, no infantry could catch them, nor could cavalry, unless it was prepared to lose three men for one.

Much depends upon proper equipment in this class of work. The sharpshooter's clothing should be of such material and cut that it would impede him as little as possible in athletic movements, such as climbing, crawling, and swimming. It should be as inconspicuous and noiseless as possible. Woollen underclothing, a heavy overshirt, stalking suit, low-crowned stalking cap, and stout but light and flexible shoes with soft rubber soles (like a tennis shoe,—

such soles, when well made, outwear leather), all tan-coloured, like a duck hunter's costume, would fill the requirements. Unless the man was very deeply bronzed by exposure, it would even pay to stain his face with a solution of oak bark, or the diluted juice of walnut rinds. This may sound absurd, but it is a fact that the first thing you see of a Caucasian, when he is motionless in cover and suitably dressed for hunting, is his white face.

There should be no stick-outs or flapping articles in the equipment. A large pocket in the tail of the jacket, as in a hunter's coat, would dispense with a haversack. Even the canteen should be fastened so as not to dangle in crawling. There should be as few straps as possible. In the whole equipment there should not be one article that would glitter in sunlight or by firelight. The very muzzle of the rifle should be browned; for, when presented at certain angles to the sun, a bright muzzle will glitter like a star, betraying the rifleman to a considerable distance. The metal parts of the gun, so far as practicable, should be wrapped with strong, heavy, water-proofed twine, especially the barrel, for ordinary browning soon wears off from exposed parts, leaving the steel shiny. The twine wrapping would also protect the rifle and telescope from injury from blows, would make the gun noiseless when accidentally struck against rocks, would prevent barrel mirage, would lessen the "jump" of the barrel when shot from rest, and would save the left hand from being burnt in rapid firing; so no forearm would be needed.

These points may seem trivial to the uninitiated, but in reality they are matters of life and death. Close attention to just such details must be paid by any hunter of big game,—and man-stalking is the same principle. Man-stalking, did I say? The word has a horrible sound. But the object of war is to crush the enemy as soon as possible, with the least possible loss to your own side. "War is never lenient, save where it is wanton." Attack against a thin line of genuine sharpshooters in cover would be suicidal. And when attack ceases to be feasible war will cease.

TRANSPORTATION IN THE PHILIPPINES

By Wm. Gilbert Irwin

A NATIVE CARRIER

THE fact that the entire railway system of the Philippine Islands at present consists of a single line of antiquated pattern, having a length of less than one hundred and twenty-five miles, gives some idea of the neglect of this economic form of travel and transportation under the long Spanish régime. In nearly all parts of the island of Luzon and the several other islands of the archipelago the snail-like carabao, or water-buffalo, and clumsy carts form the only means for transporting heavy loads, while the diminutive pony and the ungainly carromato, as the usual native carriage is called, are used for travel.

Under Spanish rule few improvements were made by the several provinces, for the petty governors found no time to take special interest in commercial or agricultural advancement. Their tenure of office was ofttimes short and at all times uncertain. In cases where particularly worthy officials made any show of internal improvement their plans were thwarted in Manila, and the greedy officials there pocketed the money which, according to the Spanish law then in force, should have been expended in the provinces where it was collected. The writer was told while recently in Manila that in half the provinces there had been no money at the disposal of the local Spanish governors for a dozen years, and he has travelled over roads in Luzon where broken bridges had remained unrepaired for this same reason.

To one who has never been more than a dozen miles from Manila little of this neglect is known. About Manila Bay there are many fine roads, but during the rainy season they are almost impassable. The roads connecting the villages are miserable excuses, and in the wet season fully half of them are impassable for any kind of a conveyance. Under Spanish rule it was a punishable offense for unofficial persons to repair public roads. The want of passable roads has been greatly felt by the American army. With this defect eliminated and a more speedy method for conveyance of supplies than the water-buffaloes and carts now used, the recent war in the islands would have been greatly shortened. Along the railway line, which extends from Manila to Dagupan, American operations were vigorous and successes complete.

The Manila and Dagupan road intersects the rich peninsula northwest of Manila and connects that city with Dagupan, a town on the east coast of Luzon, which will eventually become an important one. To be exact, the length of the line is 122 miles. While in the islands the writer made a close study of

GENERAL OFFICES AND DEPOT, AT MANILA, OF THE MANILA AND DAGUPAN RAILWAY

this primitive attempt at railway operation. In September, 1898, he accompanied the first party of American officers, soldiers and civilians that ever rode over the entire length of the line. Later, during the insurrection, the line was traversed under various conditions, sometimes on an open box-car, sometimes in the queer compartment coaches, and often on an engine.

The road runs diagonally across a somewhat rolling country with a general elevation slightly above the sea level. On either side are high mountains. At Dagupan the valley opens upon the Gulf of Lingayen, while its south end is bounded by Manila Bay, Pasig River

A SIGNAL POST AND TURN-OUT

and Laguna de Bay, the largest and most important lake in the Philippines. The valley included in this area comprises one of the most resourceful portions of Luzon, and, with the bordering mountain strip, includes all of the present territory of the six provinces, namely, Manila, Balucan, Pampanga, Tarlac, Nueva Ecija and Pangasinan, in which the Spanish first began the work of subjugation in Luzon.

Imagine a wide, level landscape with the view intercepted at many points, and often entirely shut off, by jungles of bamboo, sometimes fifty feet high, and these intertwined with banana and other palms and shrubbery; the open spaces occupied by great fields of rice and sugar-cane; queer villages of bamboo huts with thatched roofs set down in field, and wood, and jungle; marshy, overflowing rivers with great sheets of water extending out through the fields, and you will have a good view of the country between Manila and Dagupan, especially in the rainy season, which prevails during a larger part of the year.

A further detail of the route traversed by the railway line will give some definite idea of the difficulties to be overcome in railway engineering in the Philippines, for the same conditions prevail everywhere. For the first fifteen miles out of Manila there is a comparatively easy grade, and but few streams are crossed. At Caloocan, three miles from Manila, the machine shops of the railway are located. These, as well as a considerable part of the line and the

different bridges, were greatly damaged by the insurgents as they retired before the American advance. After leaving the hills behind and traversing half a dozen miles of swampy rice fields, Malolos, the eighth station from Manila, and the former Filipino capital, is reached. Nine miles from Manila is Calumpit, and in this distance twelve streams are crossed, all of sufficient volume to be called rivers. The third town from Calumpit is San Fernando, the largest inland town on the island and the seat of extensive sugar mills. At Bamban, twenty miles farther on, we reach the mountain section, and while from this point on to Dagupan the difficulties of bridge building are eliminated, the steep grades encountered add to the engineering obstacles.

The railway is of 3 feet 6 inches gauge, and is laid with 45 pounds to the yard steel and iron rails. The ties are of the finest hardwood, obtained from the forests along the line. On the entire length there are sixty iron bridges. As compared with the fairly substantial character of the road-bed, the rolling stock is very light. In speed and capacity the locomotives are insignificant, being of less than ten tons burden. The usual speed varied from fifteen to twenty miles an hour, and when the American troops took posssesion their railroading astonished the natives, the speeds being frequently doubled. Compartment coaches are used, and these are divided into three classes or apartments, each apartment seating eight passengers. The few first-class coaches are provided with comfortable cane chairs, while the second-class apartments have rough wooden benches, and the third-class are bare and are usually crowded with natives carrying baskets and bundles of all descriptions. An ordinary train is made up of eight or ten carriages, most of them third-class, and the fare ranges from two to five cents, Mexican, per mile. The bulk of the freight now carried is made up of rice, sugar, hemp and building material, and the rates on all classes of traffic are considerable.

A NATIVE CART, DRAWN BY A WATER BUFFALO

Owing to the exacting requirements of the Spanish authorities the buildings on the line are first-class. The Manila depot is a well-arranged two-story wooden structure, 70 feet long and 45

feet wide, with train sheds 325 feet long, covering four tracks. Before the recent insurrection natives were largely employed in operating the road. They served as clerks, telegraph operators, station masters, conductors, engineers, firemen and mechanics. Cheap labour enabled the inexpensive operation of the road. The wages paid ranged from about fifteen dollars per month, Mexican money, for labourers, to forty for clerks, station masters, engineers and similar employees. The term Mexican is in general use in the islands in referring to money values, taking precedence over the Spanish.

GLIMPSES ALONG THE MANILA AND DAGUPAN RAILWAY

The first step towards the construction of this road was taken by the Spanish Government in 1875. At that time an elaborate scheme for the building of railway lines in the Spanish colonies was formulated. It provided for lines constructed by the colonial governments or by subsidised companies, and admitted of cessions being granted by the colonial governments. Ten years later the government offered a subsidy of $7650, Mexican, per mile for a line between Manila and Dagupan, but none of the Spanish capitalists accepted the offer. A subsequent offer, including a guarantee of 8 per cent. on a maximum cap-

THE STATION AT CALOOCAN

ital of $49,643, was accepted in the autumn of 1886 by a London firm of contractors. The road, in accordance with the terms of the concession, was completed within four years from July 22, 1887. At the end of ninety-nine years the road was to revert to the government without compensation. It is difficult to see why a government so accustomed to extortion and the imposition of restrictions could grant such a liberal concession.

This pioneer road has been of untold benefit to the country through which it passes. The damages done to the line during the recent war have all been repaired, twenty-five miles of track having been shipped from San Francisco to be used in the work of reconstruction. Already American capitalists have turned their attention to the matter of railway construction in the Philippines. As soon as the insurrection is finally blotted out, the work will be commenced, and upon its heels will undoubtedly follow the phenomenal development of the agricultural resources of this garden spot of nature and the opening up of the timberlands and mineral wealth of the islands.

Manila has a primitive street-car system. The cars, while of a fairly good pattern, are drawn by the poor little ponies over a miserable road-bed. With but little expense and labour these lines could be changed and made suitable for fairly efficient and profitable working. There is an old tramway line extending from Manila to Malabon, a distance of about five miles, but this has long been out of operation. In lieu of better methods of travel the natives at present use the numerous streams and canals which are easily accessible to their queer little craft. As a field for railway work the Philippines present bright possibilities, while Manila and the other larger towns of the archipelago will soon be ready for modern street-car lines, electric lighting and other modern improvements.

STEAM PIPE ENGINEERING.

By W. H. Wakeman

ABOUT fifteen years ago the writer took charge of the first Corliss engine that had ever been placed in his care. The pipe which carried steam from the boilers was of cast iron, in lengths of about 8 feet, with pipe and flange cast together, and bolt holes cast in the flanges. No machine work had been done on the faces of the flanges, and it was plain that the entire pipe had been put into service just as it came from the foundry. When the piston commenced a stroke it caused a rush of steam through the pipe that could be heard plainly in the engine room and its vicinity, and when the dash pot rapidly closed the valve it caused a shock in the steam pipe, and as the performance was repeated at regular intervals, the result was a vibration of the whole line that was at once dangerous, troublesome and unsightly; dangerous, because such vibration will result in cracks and fractures if long continued; troublesome, as it would loosen the gaskets used to pack the joints, causing them to blow out frequently; and unsightly for obvious reasons.

The boilers were set at right angles to the steam pipe, so that the successive shocks would cause them to rock until the safety valve levers danced and the valves would not remain closed. This plant had formerly been equipped with a large battery of plain cylinder boilers, set so that the steam pipe was parallel to their length, but these had been taken out and a small battery of tubular boilers substituted.

Observation of the plant in operation, and a calculation which showed that the area of the cylinder was eleven times that of the steam pipe, demonstrated that the pipe was not large enough when the speed of piston was considered, although this was only 480 feet per minute. When steam was admitted to the cylinder, the pressure in the pipe was reduced several pounds, and when the supply was shut off, it rose until slightly above the boiler pressure; hence the repeated shocks. As the faces of the flanges were not finished, only soft packing could be used on them, and, in addition to the vibration, the following conditions assisted in rapidly destroying the gaskets. The main body of the pipe was covered with a low grade of pipe covering, leaving the flanges exposed, the result of which was that water would flow along the bottom of the pipe when the engine was running, and collect there enough to make its way through the joints and drop on the floor. The contraction at the joints left the gaskets partially loosened and the pressure would blow them out.

Two rods of ¾-inch round iron were threaded on one end and flattened and upset on the other until a hole large enough to take one of the flange bolts could be punched in it. Two of these bolts were taken out of a joint near the centre of the line and longer ones substituted, so that the rods could be bolted to the flange. Eyebolts were put into the timbers overhead, and the threaded ends of the rods put through them so that when the nuts were screwed up the pipe was drawn towards the engine. Two other rods and eyebolts were used in the same way on a joint about 8 feet distant, except that when the nuts were screwed up they drew the pipe from the engine, so that between the two pairs it was held steady, for the vibration was

eliminated. A line of pipe should not be fastened in this way near either end unless there is an expansion joint in it, as the expansion will then be all in one direction, and probably cause a break; but by locating the support in the middle, the expansion will be divided, and the liability of fracture will be much less.

Very little cast iron pipe is used for new plants at the present time, and its abandonment is a move in the right direction, for it is uncertain material at its best, while pipes that have been broken show that they contained thin spots, so that they would have been thrown out as dangerous long ago had their condition been known. Steel pipe made with riveted joints seems to be all that can be desired for this service, when properly made, and hung so as to avoid trouble from the inevitable contraction and expansion due to change of temperature. Next to this, heavy lap welded wrought iron pipe is to be preferred for strength and durability. Screwed joints for large sizes are not favoured so much as they formerly were, although many of them are still used.

While watching the making of some pipe about 12 inches in diameter, the writer noted that heavy cast iron flanges were used, threaded on to the pipe. Care was taken, however, in every case to have the end of the pipe project beyond the flange, after which the rough flange was faced off ready for packing. In this way the ends of the pipe are brought into contact with the gasket, and here the packed joint is so made that no steam pressure comes upon the threads, the only use of the flanges being to hold the pipe together endwise. This is all very well in theory, and if actually done in practice it is well, too; but the trouble will be to get the gasket into its proper position to do good work and yet not have it project into the steam space, for if it is allowed to do this, water will be trapped in the lower part and cause trouble.

The result of making such a joint as this is to bring a very great compression pressure upon a narrow gasket, thus making the pressure per square inch of surface very heavy, which, in practice, has proved to be much superior to a larger gasket, for in that case the compression pressure is low, making the gasket more liable to blow out, and greatly increasing the chance of leakage.

Another plan is to turn a groove in the face of the flange and put a round gasket of solid rubber or of thick tubing into it, and as another groove is turned to correspond to it in the connecting flange, there is very little chance of its blowing out. One objection to this is that when a gasket must be renewed it is necessary to move the pipe endwise for several inches in order to afford room for cleaning out the grooves, and this is not always convenient. In such a case the engineer must choose between putting in a system that will need frequent repairs, which may be easily made, and one that is very durable but is troublesome to repair when a failure does occur. Modern practice seems to favour the latter in a majority of cases.

Another form of packing consists of a copper rod about ¼ inch square for a gasket. Sometimes a groove is turned in one flange for it, or it may be used on plain surfaces. A groove is put in the centre of this rod or bar, in order to reduce the surface in contact to the lowest possible point, so that when the nuts are screwed up the soft metal will be forced into any hollow places that may exist on the flange and prevent leakage.

Broad gaskets of thin sheet copper, corrugated in form, are frequently used, and are favourites with many engineers, for they never blow out, last a long time, and are easily removed, for when they are taken out they do not stick to the flange, but come away in one piece, and when the pipe is moved endwise ¼ inch the space obtained is sufficient to admit a new gasket.

Where turned bolts and reamed holes are used, it is practical to leave raised spaces, ¼ inch wide, on the flanges and make ground joints, so that no packing is required; but this plan is expensive in first cost. When we consider, however, that many plants are expected to

be run almost continuously, and think of the expense and annoyance of a shut-down for repairs to steam pipes, it becomes evident that the extra first cost will probably prove to be a good investment. Whatever plan is adopted for making these joints, a good bearing must be secured inside of the bolts, as otherwise steam will leak through the bolt holes; but attention should be called to the necessity of bringing this bearing as near the bolts as convenient, because the tendency of screwing up the nuts is to spring the flanges, and in some cases this is done to an extent that brings their outer edges together. This relieves the steam joints of a portion of the clamping pressure and makes them more liable to leak than if the whole stress of the bolts were brought to bear upon them.

With the ordinary form of flange construction it becomes a difficult matter to tighten up the nuts, because they are so near to the hub of the flange that nothing but a solid wrench with an open end can be used on them. This evil would be overcome if the whole flange were made as thick as the hub, but this means great addition to the weight, which is already excessive for large pipes, so that it is advisable to simply cast a hub around each bolt hole that will extend as far back as the hub of the flange; the whole space between the nut and the pipe will then be available. Where there are flanges not made in this way one thick washer should be used on each bolt; this will secure the same result.

Another point to be taken into consideration is that where a flange is made of the same thickness throughout its entire width its diameter may be made less without bringing the nuts nearer to the pipe than they often are to the hub of the flange. This would bring the strain caused by screwing up the nuts nearer in line with the pipe, which is a desirable feature; and it would also make a very strong flange, but it would be clumsy in appearance.

A consideration of the appearance of these flanges reminds one that they are almost always exposed to view and also to the cooling effect of the air while the remainder of the piping is nicely covered. This is probably done to make repairs more convenient, but the flanges present a large amount of radiating surface that causes much condensation of steam. Some of the makers of gas engines are wise enough to utilise this principle to their advantage, for they find that an irregular or ribbed surface radiates heat for which they have no use much faster than a smooth, plain surface, and in the rough and irregular flange the same principle operates, although this is not always appreciated.

It might be claimed that flange joints should be made so that they will not leak, but while this is desirable, it seems to be difficult to obtain; therefore, a covering that can be easily and quickly removed should be provided for every one of them. It would prove a paying investment.

Men who are well posted on the subject think it strange that the steam pipe for an automatic engine should be made larger than for one of the throttling type, when the former requires less steam to run it than the latter, the load and other conditions being equal. The explanation of this apparent inconsistency is not difficult, for while an automatic engine may take all the steam necessary to complete a stroke by the time that one-fifth or one-fourth of it is completed, thus requiring a large pipe in order to supply it very quickly, the throttling engine will take steam for three-fourths or seven-eighths of the stroke, thus making it possible for a smaller pipe to deliver the whole quantity, as the amount per second is less in the latter case.

Where a steam pipe is too small, there is danger not only of its vibration, as already noted, but also of loss of efficiency; for wherever there is a reduction of pressure in a pipe line conveying steam, air, or water, it is attended by some loss due to increased friction, even though it may be claimed that such friction reappears in the form of heat. The loss may be very small for each stroke when we consider the number of

strokes made in ten hours by an engine making from 60 to 100 revolutions per minute, but the total is worthy of consideration. With reduced pressure from too small a steam pipe for an automatic engine there comes also a delayed point of cut-off, calling for a greater volume of steam and raising the terminal pressure in the cylinder.

The points to be considered when designing a main steam pipe are as follows—1st, the pressure to be carried; 2d, quality of the steam; 3d, length of pipe; 4th, manner in which the engine takes it; 5th, the drop in pressure that will not be considered objectionable. Numerous experiments have demonstrated that a steam drum, located near the engine, is a great help to a small pipe, as the drum is filled to boiler pressure when the steam valve of engine is closed; then when it is opened the expansion of the steam prevents a great fall in pressure, and on this account alone some of the separators that have been applied to steam pipes and located near the engine have proved very beneficial.

As a rule, a separator should be located as just noted, but it may not be the best place in all cases. In one instance several boilers discharged their steam into one main pipe, on one end of which was a blank flange. A "slug" of water was started in the pipe, struck the flange squarely, broke it, killed three men, and wrought havoc with the timbers in that locality. The boilers undoubtedly supplied wet steam, or, more properly speaking, water and steam; but if a separator had been located in each branch pipe, near the boiler, no such accident would have happened with the otherwise correct arrangement of piping such as was found here, for steam would not have been condensed fast enough to do harm.

There is at least one separator on the market that is intended to be put in the steam space of a boiler where it will not be exposed to the cooling effect of the air. It takes the water out of the steam before it leaves the boiler, and drops it back into the water space through a drip pipe so arranged that the water cannot back up into it. This will certainly prevent the trouble before mentioned, caused by water in the bottom of the steam pipe, for ordinary lengths, and when it is necessary to conduct steam for great distances it will pay to put in a separator and steam drum combined near the engine, in addition to the separator at the boiler.

In a plant under the writer's care the boilers furnish very dry steam, and the engine is within 14 feet of the ends of the boilers. As the exhaust steam is used for other purposes besides feedwater heating, a separator was put in the exhaust pipe beyond the heater, so that all of the water resulting from cylinder condensation and heating of feedwater and also the cylinder oil are taken out, leaving the exhaust steam as dry and clean as the live steam.

About twenty years ago the writer had charge of a plant where the first section of steam pipe was hung in a horizontal position, then turned downward and went beneath the engine room floor, and then turned upward to the cylinder. This proved a dangerous plan, for water would collect in the U-shaped portion thus formed and cause trouble unless carefully drained off. As there is always a possibility of this being neglected, sooner or later, some other arrangement should be adopted.

A point which seems to be always in dispute among engineers is the direction in which the main steam pipe of a plant should pitch. If it rises all the way from the boilers until near the engine and then turns downward, the water from priming and condensation must flow against the current of steam, if it follows the law of gravitation, and unless the pipe is large enough to allow the steam to travel at a slow rate, the water will not drain back to the boiler, but will fluctuate back and forth under ordinary conditions, and when a heavy load is thrown upon the engine, causing an extraordinary rush of steam through the pipe, this water will be gathered up and thrown into the steam chest and cylinder, where it may cause serious damage. On the other hand, if the pipe pitches toward the engine, it will be con-

tinually drained by natural means, so that the danger of an accumulation of it, sufficient to do any harm, will be reduced to a minimum.

The risers should be carried from the boilers up to a height equal to that of the main pipe, and a stop valve should be located at the highest part of each, so that there will be no danger of water accumulating above the valve when it is shut. In the writer's plant this important point was not considered when the 6-inch risers were put in, and the consequence is that when one boiler is shut off water accumulates and fills five feet of 6-inch pipe. Near the valve the water is nearly cold, and if the valve is opened, even with the greatest care, excessive water hammer is the result. Drip pipes, therefore, had to be put in to remove the water; but this is a makeshift, for drips would not have been needed if a proper plan had been adopted for the risers.

Let us consider the probable effect of a failure to properly drain one of these risers when steam is raised after cleaning the boiler to which it is attached. The boiler is filled with cold water, a fire is built under it, and steam is raised to about the same pressure as that already existing in the main pipe. Through a mistake on the fireman's part, however, it goes a few pounds higher than was intended; then when the stop valve is opened the water standing above it is projected into the main pipe and is hurled with great force through it until a tee with a plug in one part of it, or some other flat spot is reached, when a break results, and if one or more men are not killed or scalded it is fortunate. If there is no flat spot in the fittings for the slug to strike fairly, it may pass to the engine, cause a cylinder head to be knocked out or other serious damage to be done.

Much unnecessary strain is brought on steam pipes on account of improper support from defective hangers, so that the joints are frequently strained and sometimes broken. In some plants the pipes are suspended from floor beams and rafters by means of chains passed underneath them. To the casual observer this appears to be good practice, but as the pipe expands the chains hang at an angle from the perpendicular; hence the pipe is raised from its position when cold, but not raised alike at all points, for as the length increases the expansion is greater. The angles of the chains are, therefore, all different, and the pipe is unevenly supported in practice, although it may be correct in theory. Where it is necessary to use hangers, they should be made stiff enough to be unyielding, with a roller for the pipe to rest on, so that it can move easily.

Where large pipes are laid near the ground they should be supported on solid foundations of brick or stone, surmounted by heavy sole plates. A substantial foot should be bolted to the pipe, with a stout wheel at its lower extremity, which will enable the pipe to move freely, without the jerky motion found in pipes that are not properly supported in this respect. It may be well here to consider the amount of movement that should be provided for, and attention should be called to the fact that while close calculations answer a very good purpose in many cases, it is better in a case like this to provide for the largest amount ever known to be necessary, even if the conditions found in any particular case call for less. The greatest amount of expansion that the writer has known of is 1 inch to each 50 feet in length, so that if this is provided for, one will probably be on the safe side.

Where expansion must be provided for, some form of expansion joint should be put in. This may be in the form of a slip joint, an L or an S-shaped connection. Emphasis is laid upon this part of the plan because it has either been improperly provided for, or else entirely overlooked in many cases, resulting in leaky joints and broken pipes.

It is especially necessary to provide for expansion when erecting the risers from the boilers, and the horizontal pipes between them and the main pipe. It will not do to use a short riser unless the horizontal pipe is long accordingly, and in no case should such a riser be less than 6 feet high. It is generally

better to use a pipe bent to about a 10-foot radius; this will spring enough to answer every purpose.

For pipes of medium size the S-shaped connection affords ample protection against the effects of expansion, and in many cases it is made of copper pipe, although this material has many failures charged against it. For very long pipes the L-shaped connection is used with good results, provided the offset is large enough to spring without breaking. No inflexible rules can be laid down that will apply to all of these cases. Much must be left to the judgment of the designing engineer.

Current Topics

STEAM raising from town refuse is a comparatively old topic, and the fuel value, from this point of view, of all that is implied by the words town refuse has been discussed on many occasions, and has been practically illustrated as well in several instances. It is, therefore, somewhat refreshing to read of the latest proposed refuse disposal scheme, which is simply to convert the stuff into fuel gas. This, later, is to be used in gas engines for electric generator driving for power and lighting, leading eventually to an energy system beside which all present and immediately prospective steam power plants would appear hopelessly antiquated. With the gas generated, of course, at one large producer station and utilised presumably right on the spot, and that spot located on the water front of such cities as have any, the question of power station coal would be satisfactorily disposed of at once, and that of water as well, for the only water that would be needed would be that for cooling the gas engine cylinders, and that could be pumped from the river and again discharged into it later. The scheme is decidedly an attractive one; it would solve some municipal difficulties as well as some encountered by private corporations; but, for the present, unfortunately, matter-of-fact figures to give a substantial, practical base of operations are entirely lacking.

A NEW use for refrigerating machinery has been found in the contemplated cooling of magazines of warships so as to prevent explosion danger from overheating. Experiments with that end in view have been made for some time, but it is only recently, with plans pro-

posed by Rear-Admiral O'Neil, of the United States Navy, that any fair measure of success is said to have been attained. It does not seem unlikely, therefore, that in war vessels yet to be built magazine refrigerating apparatus will be one additional adjunct to the already long list of marine auxiliary machinery.

CONCRETE is not usually classed among the combustibles, so that the recently reported taking fire of a mass of that compound in the boiler room of an electric power station is particularly interesting. A simple enough explanation for the occurrence was, however, found in the fact that the concrete, which, by the way, was used for the foundations of two of the boilers, consisted of one part in seven of boiler furnace ashes, and that the brick lining under the boilers was omitted in one place, so that the furnace temperature was readily transmitted to the concrete. The latter, as the *Electrical Review*, of London, tells it, became ignited, and the whole block, 8 feet deep, disintegrated; in consequence it was found necessary to pull down the brickwork of the boilers, and remove the whole of the concrete block. The calorific value of the boiler ashes employed must have been considerable, and in the present scarcity of coal, the *Review* facetiously adds, engineers may find it worth their while to stoke with concrete!

AN interesting illustration of what may be accomplished by fertility of resource is afforded in a couple of lathes, arranged tandem fashion, in the machine shop of the United States Navy Yard at Brooklyn, N. Y. It appears that several 35-foot propeller shafts had, each, two sleeves shrunk upon them which were to be turned, the sleeves being spaced about 18 feet apart, and in addition some work was to be done on one end of each shaft. There was, however, no lathe in the shop with a bed of sufficient length to handle the work, and two 20-foot lathes were, therefore, arranged, end to end, the tailstock being removed from one and the headstock from the other. It was intended, when the idea first suggested itself, to use only the carriage on the lathe containing the headstock, turning first one sleeve, then removing the shaft, reversing it, and turning the other sleeve; but with the arrangement finally adopted both sleeves were finished in a single setting. To this end both of the carriages were used, having been firmly connected by a suitable length of angle iron. The lead screw of the furthest lathe was disengaged from the carriage, and all that remained was to set the tools of the two carriages and go ahead.

CONCERNING the effect on British commerce of the war with the Boers in South Africa, the London *Iron and Coal Trades Review* says:—"Whatever the issue of the war, our commerce and industry are bound to suffer, and that probably to a much larger extent than any other British interests. The cost of the war will be very serious,—much more so than was originally anticipated. This will involve a great increase of public burdens. The taxation of the country must inevitably rise to a figure that can only now be dimly appreciated. Our great industries must pay, as they always do, a very large share of that increased taxation. This must reduce the margin available for profits, and may, indeed, cause them to disappear. But this is not all. The business of this country is very largely conducted in reliance on borrowed money. When money is cheap, all is well. When money becomes dear, industry must suffer. Already money has become considerably dearer, and it is likely before long to become more so. Let us consider the effect of this difference on, say, a colliery producing 1000 tons of coal a day. Such a mine may, and often is, to the extent of one-half of its whole capital dependent on borrowed money, which may mean that the borrowers will now have to pay 6 or 7

per cent., instead of 3 or 4 per cent., as hitherto provided for. On a sum of £100,000 this would mean an additional annual charge of £3000, which often makes all the difference between a reasonable profit and an absolute loss. The same considerations equally apply to all other industrial undertakings.

"BUT an even more palpable danger is at this moment threatening our great industries in the withdrawal from them of the men who have now been called upon to take part in the campaign. The establishment strength of the reserves and the militia, taken together, is over 215,000 men. There can be little doubt that the whole of this force is now withdrawn from active industrial life for a practically indefinite period. If these men were wholly engaged in our great industries the effect on our industrial outlook would be disastrous. Happily, however, only about one-half of them, so far as can be ascertained, are so employed. Of the militia, whose enrolled strength is rather over 113,000 men, 20,000 are mechanical labourers, 13,000 are miners, and 10,000 are artisans. The labourers may be almost immediately replaced. The miners and artisans cannot be replaced for a considerable time, as there are practically none now out of work who are fit to work; and already, in not a few branches of manufacture, as well as in some of the coal-mining districts, there is an absolute scarcity of men. If the proportion of men in the reserves who have been, or are, employed as miners is much the same as in the militia, then the effect of the calling up of both forces may be to withdraw nearly 25,000 men from the mining ranks, which would mean close on 5 per cent. of the whole. It is, however, probable that not more than 2 or 3 per cent. of this proportion are engaged in our coal mines; and, although the retirement of this number will not create a coal famine, it is not likely to make coal any cheaper. If we add to the 20,000 mechanical labourers ascertained to be in the militia a further 15,000 for the reserves, we have a total of 35,000 men retired from active mechanical industry, of whom a very large proportion are employed in iron and steel works, foundries, and engineering and shipbuilding establishments. It will take some time to draft new men into their places, but probably this can ultimately be done without creating such confusion as would involve a serious check to industry. All the same, the outlook, from the manufacturers' point of view, is far from satisfactory.

"BRITISH trade and commerce are bound to suffer in other directions. The withdrawal of so large a number of vessels from regular lines for transport service has created considerable disorganisation in the regular passenger and mail business, and this effect is likely to become more acute than hitherto. Moreover, there may be, and probably will be, some dearth of shipping for the ordinary purposes of trade. But with our magnificent maritime resources this inconvenience cannot be either great or long-continued. Freights are likely to rise; so also will the prices of commodities. Every British subject must feel the pinch."

MAGNETIC chucks for machine shop use, and magnetic holders for electric incandescent lamps, by means of which a lamp may be made to stick to any conveniently placed piece of iron or steel, have become familiar devices within the past year or two and have met with a fair measure of favour. Based upon the same principle we now find a friction clutch, if it may be so termed, devised by Mr. B. J. Arnold, of Chicago, in which magnetic attraction is substituted for ordinary mechanical pressure between the friction surfaces, and, according to all accounts, this new idea has been worked out practically in a very successful way. The working parts of the clutches are composed of metal having a high permeability, so arranged as to become mag-

netised upon the passage of direct current through the coils with which they are provided. The two parts of the clutch can be attracted together in this way with a pressure far in excess of that obtained in mechanical clutches, and it is only a question of making the clutches large enough to enable them to transmit power in any desired amount. The energising circuit is controlled by means of a switch placed at a convenient point, which is quite a decided advantage over the ordinary friction clutch. It thus becomes possible in throwing a generator in or out of service to control it entirely from the switchboard where all the regulating devices and measuring instruments are within reach of one attendant. The magnetic clutches also possess the advantages of neat appearance and compact design. Even in the larger sizes the space occupied upon the shaft is not much more than twice the diameter of the shaft, and by using a flange forged solid on the end of the shaft they can be made to occupy even less space when used as cut-off couplings. Owing to their having no projecting surface or parts to catch the air when in operation the windage resistance is negligible. The greatest advantage, however, of this form of clutch over others is the fact that it is self-contained, —the "action and reaction" being within the clutch itself, and consequently there is no resulting end thrust upon the shaft bearings and no additional friction load due to the operation of the clutch. A recently designed clutch of this kind, intended to transmit 3000 H. P. at 150 revolutions per minute, measured 100 inches in diameter and the amount of current required to properly energise it was claimed to be no more than would be used by about four 16-candle-power incandescent lamps.

Apropos of trades union restrictions upon employers, and union persecution of workingmen who will not bow down altogether to union dictates, it is worth calling attention to the outcome of some recent court proceedings at Buffalo, N. Y., instituted by a linotype machinist, formerly employed in the composing room of a daily newspaper, against the president of one of the branches of the Typographical Union. The plaintiff had sued on the score of conspiracy in forcing him out of his job because he had refused to take out a card in the typographical union, and during the trial it was shown that he was a member of the machinists' union and did not care to join another. The typographical union called out all the union printers in the office of the paper concerned and ordered them to remain out until the plaintiff was dismissed. This was on June 30, 1899. In order to avoid a strike, the proprietor of the paper was forced to discharge the plaintiff, and since then the latter has been out of employment, although he has diligently sought work. In his complaint the plaintiff asked for damages at the rate of $25 per week, the amount he was receiving in the office of the newspaper, and $25 for expenses in trying to obtain another position. In his decision, Justice Henry A. Childs, of the Supreme Court of Buffalo, before whom the case was tried, told the jury that the plaintiff was entitled to recover, and the jury accordingly returned a verdict for $650. A motion for a new trial was denied, and all the other members of the typographical union are now facing the likelihood of criminal proceedings being brought against them individually for conspiracy. The plaintiff announced also that he would sue the union to be re-instated in his position. Altogether, the case furnishes an instructive lesson to labour agitators and their subjects, who either do not know enough, or do not care, or perhaps do not dare to think and reason for themselves.

It is an interesting fact that lead pipes extend back to the dawn of history. They were more or less common with all the celebrated nations of old, and in the early cities of Asia, Egypt, Greece, Syria, and others they were used to convey water wherever the pressure was

too great to be sustained by those of earthenware. All the ancient lead pipes yet discovered are said to have been made from sheet lead, strips of the metal of sufficient width having been folded into tubes with the edges united by solder, and while there appears to be no information extant of the method of making such pipes previous to the Roman era, it is reasonably safe to assume that the Roman pipes were but copies of those made by the plumbers of Babylon and Athens, Egypt and Tyre. Historical records tell us that Roman plumbers generally made the pipes in ten-foot lengths, with the thickness of the metal depending upon the diameter, and the latter, judging from large quantities of Roman lead pipes found in different parts of Europe, varied from about one to twelve inches. Some of the pipes are very irregularly formed, their section being egg-shaped rather than circular. Large ones, belonging to the public, had the name of the consul under whom they were laid cast upon them; others that supplied the baths of wealthy individuals carried the owners' names; and sometimes, too, the maker's name was upon them. In the explorations of Pompeii, which was but a small provincial town, a great many tons of the pipe have been found, and it may readily be inferred from this that, altogether, the Roman consumption of lead for pipe making must have been enormous. Indeed, as Pliny observed, "Lead is much used with us for sheets to make conduit pipe."

One of the many important uses to which nickel-steel has been applied is found in the making of the hydraulic cylinders employed in the compression of armour-plate and heavy steel ingots, the power exerted in these running up into most formidable figures. In a recent paper before the American Institute of Mining Engineers, Mr. David H. Browne tells, for example, that at the Parkhead forge, in Glasgow, a cylinder for a 12,000-ton hydraulic press was cast of nickel-steel. It weighed, as cast, 143,360 pounds, and was 72 inches in diameter. The machined cylinder weighed 76,160 pounds and showed an elastic limit of 56,000 pounds, with a tensile strength of 92,200 pounds per square inch. At the Carnegie Works, at Homestead, Pa., it was discovered in 1896 that the five-piece cylinder of the 10,000-ton forging-press was developing a crack. As the makers could not replace this cylinder in less than eleven months, it was hastily decided to cast a cylinder of open-hearth steel, using enough nickel to insure maximum strength. A hollow ingot, of 0.25 carbon, with 6 per cent. nickel, weighing, with the sinkhead, 140 tons, was successfully cast. Considerable difficulty was experienced in erecting machinery of sufficient size to handle such a casting, but an impromptu lathe was finally erected, and the ingot was turned to the finished shape, in which it weighed 90 tons. This cast cylinder has now been in use for nearly two years and shows no signs of wear. It withstands an interior pressure of three gross tons to the square inch, and is undoubtedly the largest casting yet made of nickel-steel for hydraulic cylinders.

But it is not only for big things that nickel-steel has found extended and successful application. There are a large number of less pretentious purposes for which it is employed but concerning which commercial rivalry prevents the publication of reliable data. For locomotive fire-boxes, boiler-braces and stay-bolts, bicycle-spokes and chains, torpedoes and topedo-nets; incandescent lamp-mantle hangers; rolls for tubing and for planished sheets; boiler-tubing, revolvers and small-arms; safety-deposit vaults; bobbin-spindles; teeth for cotton-pickers, and for a great variety of purposes for which some peculiarity, either of strength, ductility or incorrodibility, gives it especial fitness, nickel-steel is rapidly making its way into popular favour. The peculiar electrical and thermal coefficients possessed by the alloys of steel with high

percentages of nickel, also suggest numerous uses in electrical appliances and instruments of precision. All the nickel-steel alloys are remarkably homogeneous, easily worked and susceptible of a high polish. M. Zetter, director of the French Electrical Equipment Company, has made numerous experiments on the nickel-steels which lose their magnetism on heating and recover it on cooling. He has used these metals in the manufacture of circuit-breakers, automatic fire-alarms and other instruments, in which an electric circuit is broken by a rise of temperature, produced either by the heating effect of the current or by an external source of heat. He finds these instruments to act with regularity and accuracy. M. Dupriez suggests that, as the temperature at which magnetism is lost and regained in nickel-steel is a regular function of the amount of nickel present, the 30 per cent. alloy which loses magnetism at 100° C. and regains it at 50° may be utilised in the construction of a thermo-electric machine for the direct conversion of heat into electrical energy.

For instruments of precision in which extreme accuracy is desirable a 36-per cent. nickel-steel may be used to great advantage instead of brass. With changes of temperature it expands and contracts only one-twentieth as much as brass, is very much stronger and more rigid, and hence allows a reduction of weight in the instrument. As it is very much less affected by moisture and corrosive gases, and retains a silvery colour and polish under adverse circumstances, its advantage for scientific instruments is very evident. The incorrodibility of nickel-steel points out its usefulness in pumps, mine-cables, wire ropes used near roasting-furnaces, and all other situations where necessary exposure to corrosive liquids or gases renders simple steel unserviceable.

CHARLES H. HASWELL

A BIOGRAPHICAL SKETCH

THERE is to-day no more interesting figure in the engineering world than Charles H. Haswell, who, though past his ninetieth year, is still engaged in active work, and is now the oldest member of the profession in harness. To by far the larger number of people he will probably always remain best known as the author of the almost universally familiar engineers' pocket-book bearing his name, though, after all, this represents only an incident in his unusually busy career. He was born of English parents in the city of New York, descending from a family of staunch Royalists, who, after the defeat of Charles II. at Worcester, migrated to Barbadoes, W. I. After a classical education, at the age of about nineteen he entered the employ of James P. Allaire, of New York, the proprietor of what was then the largest steam engine building shop in the United States. There he laid the foundation for much of his practical engineering knowledge, and in 1836 entered the United States Navy as chief engineer, being commissioned engineer-in-chief in 1843.

During his service in the navy, in 1837, he designed and constructed the first steam launch, the *Sweetheart*, which, on her maiden trip on the East River, at New York, was saluted by steamboats and assemblages of people

on the piers. He also designed the machinery for ten war vessels. After retiring from the navy in 1851, he built several merchant steamers and designed and built various other important engineering structures as well, his work collectively giving him a national reputation. In 1853 Emperor Nicholas presented him with a diamond ring for some professional service. Mr. Haswell was the first, in 1847, to apply zinc in a steam boiler and subsequently in the hold of a steamship to arrest the corrosive action of the salt water. This use of zinc was nearly thirty years previous to its trial in Great Britain as a new invention.

Upon the organisation of the Engineer Corps of the Navy by Congress, the grade of Engineer-in-Chief was established, and a man from civil life appointed to it. Soon after this the *Missouri* was ordered home to Washington, to test a novel design, a horizontal smoke pipe, and because Mr. Haswell, the chief engineer, would not agree that the scheme was practicable and that two pipes of 3½ feet in diameter were equal in capacity to one of 7 feet, he was held to be disrespectful to his superior officer, and suspended from duty. Upon the trial of the pipes, it was manifested that Mr. Haswell was correct, and he was told that as soon as the old pipe was restored the vessel would proceed to the Mediterranean, and that if he would apologise for his "insubordination" he would be restored to duty; to which he replied:—

"I prefer to submit to injustice from others than do it to myself. I decline an apology, as I owe none."

He was then detached, and very soon after appointed to design and superintend the machinery for four revenue cutters, and shortly afterwards that of a steam sloop at Pittsburgh, Pa. In 1843 he was ordered to Washington to discharge the duties devolving upon the Engineer-in-Chief, who was officially ignored, and in 1845 he was promoted to that position, which he held until 1851, when President Fillmore appointed a civilian to supersede him, but restoring him his rank as Senior Chief Engineer. In 1848 Mr. Haswell was a member of the board that designed four steam frigates, one of which was the well known *Powhatan*.

In 1850 he was ordered to the Mediterranean, but, as his health seemed to preclude such service, he was condemned by a board of surgeons, but notwithstanding this, an acting chief clerk of the Navy Department, from personal animosity, refused to acknowledge the decision of the board. Mr. Haswell proceeded to the Mediterranean, but soon after returned home, having been declared unfit for active service from ill health.

A professional feat of exceptional character was the design by Mr. Haswell, in 1847-48, of the entire engine and boiler equipment of the United States steam frigate *Powhatan*. Owing to a lack of professional and clerical aid, and the urgent requirements of the service and the contractors, Mr. Haswell was compelled to proceed with the design and details of both engines and boilers without a general design, and he personally designed every detail and made the working drawings with his own hands in the intervals between attention to necessary duties of his office as engineer-in-chief of the Navy. And with this it should be stated that the design of the engines was novel in some parts, and wholly novel in the fact that the engines were set in wrought iron frames,—the first construction of its kind. This feat is unprecedented in designing work of such magnitude, and is historically so recorded, and, considered with the remarkable success of the *Powhatan's* engines, furnishes a valuable index to the rare professional accomplishments of Mr. Haswell.

Prior to 1839 the construction of all steam boilers was restricted to the ordinary merchantable plates of metal of uniform dimensions; but when the boilers of the United States steam frigates *Missouri* and *Mississippi* were designed, Mr. Haswell laid them down full-size on the mould loft floor of the Navy Yard at Brooklyn, and defined the dimensions of each of the required plates to

suit their location in the boiler; and in accordance with this, they were rolled and trimmed. This was the first trial of such a proceeding and one that is now of universal practice.

In 1893 Mr. Haswell retired from the position of surveyor of steamers for the marine underwriters of New York, Boston, and Philadelphia, which position he had held since 1851. He designed and located the buildings on Hoffman Island, in New York harbour, the crib bulkhead at Hart's Island, the foundations of several of the large buildings of New York City, and supervised also the testing of the capacity of the water works at New Bedford and Chicago. He is now consulting engineer for the Board of Public Improvements of New York, and in addition thereto is directing and superintending the extensive constructions and improvements at Riker's Island, near New York.

Mr. Haswell, as already mentioned, is also the author of an engineers' and mechanics' pocket-book, now in its sixty-fourth edition, and of a text-book on mensuration and also on book-keeping, besides a volume entitled "Reminiscences of an Octogenarian, of New York City, 1816 to 1860."

In 1897 he attended the convention of the Institution of Naval Architects of Great Britain, at which were professional representatives of every civilised nation, and at this he was declared to be the oldest living engineer in the world.

At the last annual meeting of the Institution a paper by Mr. Haswell on "Reminiscences of Early Marine Steam Engine Construction and Navigation in the United States," was read by the secretary, and the president, the Right Hon. the Earl of Hopetoun, G. C. M. G., said in reference to it:—"Gentlemen, may I remind you that Mr. Haswell, the author of this paper, is, I fancy, about the oldest practising engineer in the world? He was chief engineer of the United States Navy at the time Her Majesty came to the throne, and that was not yesterday. I may also remind you that he was present at the International Congress held about a year ago, and was about the youngest of us,—he was here, there, and everywhere. I hardly supposed there would be any discussion on this paper, which is a record of facts; and I, therefore, propose that the secretary be authorised to send our best thanks to our veteran friend for his kindness in sending this paper over."

PHOTO BY DABBS, PITTSBURGH

C. M. Schwab

PRESIDENT OF THE CARNEGIE STEEL COMPANY, LTD., PITTSBURGH

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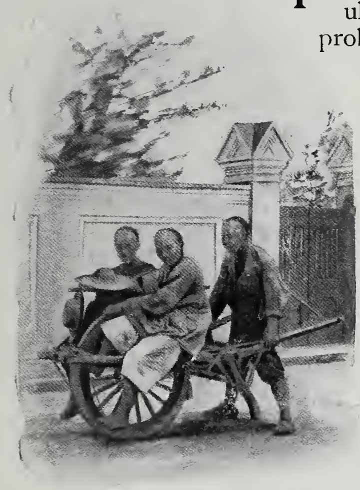
ENGINEERING IN CHINA

By G. James Morrison, M. Inst. C. E.



A CHINESE WHEELBARROW

IT is no new thing to find men speculating on the probable effect on the world of the opening-up of China, but attention has, of late, been specially drawn to that country by the events which followed the Japanese war of a few years ago, and numerous travellers have visited it, sometimes in the interests of individuals or syndicates, and sometimes simply with a view to giving to the public their ideas regarding the future of the Chinese Empire, and the prospect of its proving a field for European and American enterprise.

About twenty-five years ago a small company obtained local permission to construct a short railway from Shanghai to the village of Woosung, where the Whangpoo, on which Shanghai is situated, discharges into the estuary of the Yangtse-Kiang. China had long had a fascination for the writer, and he gladly accepted the position of engineer and general manager to the line, although it was barely ten miles long, and was on a very narrow gauge, so narrow that there was no risk of its being adopted as the gauge of China. The writer believed that the inhabitants of any country, once seeing and making use of a railway, would never rest until, by hook or by crook, they got main lines, constructed wherever they could prove useful, and he fancied that, as engineer of the pioneer railway, he would be in a good position to take a leading part in these enterprises.

The first half of the line was opened on July 1, 1876, but in less than two months traffic was stopped by order of the British Minister on account of trouble with the authorities, caused by a man having been run over. This led to negotiations with the higher Chinese officials, who began by questioning the validity of the permit, and though they never completely sustained this view, it was impossible for the company to prove that their permit was as full as they could have wished, and as a compromise the Chinese authorities agreed to pay to the company the cost of the railway, with the addition of a small bonus, and gave the company permission to work the line for one year, which thereafter was to belong to the government.

The company gladly agreed to this

QUEEN'S ROAD AT HONGKONG, SHOWING THE HONGKONG AND SHANGHAI BANK

arrangement. Their object in making the line was to introduce railways into China, not to make money out of this one enterprise, and it seemed to them that this arrangement would result in the experiment being made at the expense of the Chinese. The writer was inclined to accept the same view, but these expectations were doomed to disappointment. The line was opened throughout its entire length in November, 1876, and run until November, 1877. During the whole of that time the trains were crowded, and one remarkable result was soon made apparent, viz., that the boatmen, whose trade, it was supposed, would be half ruined, were among the greatest gainers. Passengers, instead of having to sail up and down about twelve miles of river, at hours settled by the tide and not fixed to suit their convenience, traveled to Woosung by train, and there took boat to Tsung Ming, the large island in the estuary, and the traffic to that island, which had always been large, increased in quantity and became more remunerative. In spite of all this, on the expiration of the time, the Chinese authorities paid the last instalment of the purchase money and on the next day began to pull up the rails.

It has been thought worth while to give this outline of what is ancient history, and what may be looked upon as a mere personal matter, because it bears directly on many proposals made with regard to exhibitions and object lessons generally, the practical results of which are, in the writer's opinion, likely to be much less than their supporters imagine.

Many of the late travellers to China have been men of great shrewdness, and have from their rank, or their financial backing, had many opportunities of observing facts connected with China and the Chinese; but the writer cannot help thinking that their views are, as a rule, too optimistic and rest on no sound foundation. Where facts are fully known, and propositions founded on them can be stated as the premises of a syllogism, any one of ordinary intelligence can draw the correct conclusion; but in human affairs this is rarely the case, and the shrewd man is he who, on partial information, can supply what is wanting and can draw a correct conclusion from imperfect premises. This power, however, of being able to gen-

eralise on imperfect data is apt to lead the best men far astray when confronted with a state of matters with which they are unfamiliar, and the statement that "human nature is the same all over the world," which, upon investigation, will generally be found to be one of the propositions on which their conclusions rest, is a statement of which the universal truth is, to say the least of it, very doubtful. Hence, the writer cannot accept the conclusion that because China has good natural resources, the development of which would enrich the government, enrich the people, and add to their comfort, and still leave a fair return on the investment of foreign capital, therefore there is a great field for all those who are prepared to supply the capital or the skill required to bring about such results.

It was long before the writer could force himself to adopt this view, and, hence, after the destruction of the Woosung Railway he remained in China, hoping against hope that he might have a hand in the great work of opening up the Empire.

During that time there has been ample opportunity of hearing and seeing a good deal, and of becoming acquainted with Chinese manners and customs and modes of thought, as well as with the physical characteristics and capabilities of the country, the writer having, for this latter purpose, travelled many thousand miles in the interior. That the resources of the country are great is very soon apparent. There are immense quantities of coal and iron, two of the greatest essentials of prosperity and progress, and if copper be placed next in the list, as it should probably be on account of its important place in all electrical matters, then China can boast of being in a position to supply all her own wants as well as having something left for her neighbours, while those whose thoughts turn to the mere speculative field of gold mining will find enough to attract them at Jehol and other places in North China.

THE PEAK TRAMWAY AT HONGKONG

It is true that little of the coal hitherto worked has been of the very highest

HONGKONG FROM THE WATER FRONT

quality; but there is in the south of Hanan bituminous coal that leaves little to be desired, and the accounts of reliable experts with regard to coal deposits in Shansi and elsewhere leave no room for doubt that if the coal mining industry were allowed free scope in connection with the mining and smelting of iron and other metals, China would provide a magnificent field for the capitalist and the mining engineer, as far as physical conditions are concerned.

So far as the writer's observations have gone, he would not place China first in the scale of countries considered as mining centres. The immense resources of such States as California, Colorado, and Montana for the precious metals as well as lead and copper, the great copper deposits of Lake Superior and the coalfields of Pennsylvania appear to place the United States on a much higher plane than China; but, nevertheless, if mining enterprise in China proves unsuccessful, it will not be for want of mineral resources.

Of China as an exporting agricultural country the writer does not feel qualified to say so much. The land is fertile, and can produce more than is required by the population. Tea and silk have long formed articles of export, while there is an irregular export of rice and cotton; but these matters interest the merchant more than the exploiter of China. That there are natural facilities for the production of the very finest teas no one can deny, and that properly conducted tea plantations would be of immense benefit to the country by reviving a decreasing trade, and would be better than gold mines to their owners, is abundantly clear; but the chances of Europeans being allowed to be directly connected with the production of tea or similar products of the soil is too remote to be worth consideration. In the case of entirely new industries, such as growing India-rubber trees in the South, which has been attempted, possibly a few determined individuals may be successful.

In the case of manufactures, the first difficulty has been overcome. Steam filatures for the preparation of silk according to European systems have been in existence on a commercial scale for twenty years in the northern provinces and for a longer time in the South. Cotton mills have been permitted to be owned by Europeans only since the signing of the Japanese treaty after the war; but already a very large number have been opened, as a rule in, or near, the foreign settlements. Shipbuilding has been carried on since the first settlement of foreigners in China, and there are a few shipbuilding and dock companies which have extensive establishments; but this work is very much localised. In addition to foreign (*i. e.*, European or American) machine shops and shipbuilding yards, there are the Chinese arsenals, in some of which work of a very high class is to be seen, and structures and guns of large size are turned out.

Putting aside railways, which must be treated of separately, the kinds of enterprises referred to above may be taken as types of those in which there may be found openings for the capitalist and the engineer; but the difficulties in the way of success are very considerable. In the first place, it may be safely asserted that the authorities actually in power do not want foreigners. The statement one so often sees in articles on the subject that the Japanese war has opened the eyes of the Chinese and shown them that if they wish to keep up with other nations they must adopt a more enlightened policy, is incorrect, or, at all events, misleading, because whatever truth there is in it depends upon the fact that the statement is merely to the effect that the enlightened policy is necessary to enable the country to progress on the same lines as the rest of the world, and it is misleading because it suggests that, in the opinion of the ruling classes, such progress is a thing to be desired. No such feeling exists in the minds of the majority or even of a considerable minority; but it is the members of this minority who are most likely to meet visitors to China, and who are more likely to be appointed to foreign missions, and whose views, consequently, are most readily im-

BRIDGE SPANNING LOOCHOW CREEK AT SHANGHAI, AND CONNECTING THE BRITISH AND AMERICAN SETTLEMENTS

pressed on the European public, and are naturally taken as representative of the views of the majority.

Nothing would please the bulk of the mandarin class better than that foreign nations should go away and leave China alone. She has done without railways, and steam cotton mills, and mines where 1000 tons of coal a day are raised by steam instead of 20 tons, dragged out by coolies, and she can do without them now. There are Europeans who may sympathise with this feeling, who may say that it is very questionable if European civilisation is better than any other, who may declare that the happiness of the greatest number should be the goal of all our exertions, and if the oriental prefers to be left alone, he should be so left. The writer does not agree with these views, but he does not intend to combat them.

One has heard of the school boy who was asked to give a resumé of a lecture on the necessity of good ventilation in rooms, and who expressed his views in the form, "Boys who sit in a close room should not breathe, but should wait till they get to the open air." Whether he was right or wrong, the boys could not help breathing, and no more can the ordinary Anglo-Saxon refrain from striving to advance and from doing all he can to impose his idea of civilisation on other races.

Much of the progress of the world is due to this cause, and our comfortable homes, and the abundance of luxuries which we enjoy are but the accumulated savings of the toil of our predecessors, many of whom worked because they could not help it rather than for the sake of individual benefit.

The Chinese have, no doubt, begun to realise the fact that foreigners are determined to exploit their country, and also that they are too weak successfully to resist this action, and they are, therefore, reduced to putting obstructions in everybody's way. In doing this, most of them are honestly convinced that they are doing their country a service, and if they cannot keep out foreign civilisation, they should at least delay its entry as long as possible.

The man, therefore, whose capital consists in his brains and his education, technical and otherwise, will have a hard fight to make any progress in China. From the Chinese he may obtain an appointment in an arsenal or on some of the public works. There are a few such men who have done much for the country.

In the Shanghai Arsenal, for instance, where probably the vicinity of the for-

eign settlement has, to some extent, affected the views of the officials, and they, recognising the importance of the work done by the foreign experts, have given them considerable power, work is turned out which will bear comparison with that of Elswick. In Nanking, on the other hand, where, at the time of the writer's last visit, no Europeans were employed, being looked on as mere workmen who drew large salaries and did little work, the machinery was in a disgraceful state; but the officials were satisfied with the production of small guns and similar articles, the manual skill of some of the native workmen having resulted in the execution of work of surprisingly high quantity under the circumstances. But while all this work is really the result of European skill and instruction, the number of European experts who have done any good for themselves is very limited, and even those who have been more or less successful have to thank their own mother wit for investments and opportunities outside of their own sphere, and eventually retire after a lifetime spent in the service of their adopted country, possibly with some small Chinese decoration, but hardly feeling that their life's work has brought any sufficiently good result.

Appointments to such undertakings as cotton mills are, as a rule, made at home. To any one anxious to see Eastern life such an appointment would, no doubt, afford a satisfactory opportunity. The mills have not hitherto been commercial successes, but it is not astonishing that this should have been the case at first when all the labour is absolutely unskilled, and success will, no doubt, in the long run, crown the efforts of the companies who have embarked in these undertakings. The man, however, who, conscious of his own ability to direct undertakings of such a character as those here referred to, goes to China with the impression that he has only to elaborate some evidently good and remunerative scheme in order to ensure its being taken up by capitalists, will certainly be doomed to disappointment.

A VIEW OF FOOCHOW

The smaller and what may be called the local industries are more likely to attract the attention of the local capitalist than of the general public at home. The capital required for mills, filatures,

THE GATEWAY TO PEKING

and docks can easily be raised by people in China, or people who have lived there; but large mining concessions not only require more capital than can be subscribed locally, but are also much more attractive to the general public, and rightly so. Large enterprises of this description, managed by men who understand China, provide good openings for capitalists and for the men whom they engage as experts.

The building of railways in China presents an opening for capitalists as well as for engineers probably destined to be more important in the near future than all the other openings which have been mentioned put together. Even when the 6000 miles of railway already spoken of are constructed, many of the necessary main lines will remain untouched, and the only point on which there can be any difference of opinion is the rate at which this work is likely to proceed.

In Europe the great civilising power of roads has been so long accepted as an axiom that it becomes difficult to understand the condition of mind of those statesmen who rule a country which boasts of a civilisation of thousands of years, and who yet have never risen to the idea of making a road, and, indeed, who hardly understand what is meant by the term. The writer may be reminded of the great stone road, some fourteen miles long, from Tung Chow to Peking, which now serves to mark the direction of the route to the capital, the traffic being carried alongside through the mud, or his attention might be called to the road made by Li Hung Chang from Tientsin settlement to the city, or the roads made from Shanghai settlement to the Arsenal, or through the city of Nanking. These last are, undoubtedly, roads; but the length is so short compared with the size of the empire that it would be ridiculous to speak of them as affecting the question, and it is not too much to say, therefore, that there are no roads in China.

The traffic is carried along the rivers and streams, or else along tracks which deserve to rank with the trails to be

seen in the sparsely populated States of America. The idea that railways may be useful for the movement of troops or similar purposes has forced its way into the mind of the Chinese official; but the idea that the country will be enriched by good transport being made available to people of all classes on easy terms, is absolutely repugnant to him. He is almost certain to believe that, while the shareholders will benefit, and perhaps the government, in the event of its being possible to extract heavy taxes from the railway company, the people, as a whole, will be losers, inasmuch as the porters and carters will be deprived of their means of livelihood. If you tell him that the number of horses and men employed in collecting goods for the railway companies in London is many times greater than the number formerly employed in transporting London goods all over the country, he will only smile incredulously. The company expects to make a profit, that profit must come from somewhere, and that somewhere is the pockets of the mass of the people of China.

With such views it is clear that the obtaining of reasonable terms is a work of extreme difficulty, and that obstruction, rather than encouragement, will be encountered at every stage. Still, against that there is to be put the fact that when the preliminary difficulties have been overcome and the work put in hand and eventually completed, the traffic will, without doubt, be enormous. The Chinese people, merchants, farmers, operatives, and others, are in the writer's opinion, exceptionally free from prejudice. They will at once take advantage of every opportunity that is afforded them of improving their position. If the people are not very wealthy, they are, on the other hand, not very poor. They are well fed and well clothed, and the enormous volume of traffic carried on in the face of stupendous difficulties is a proof that, if obstructions be cleared away, traffic will increase by leaps and bounds, and of the eventual success of all the suggested railways, provided only they have a fair chance, there can be no doubt in the mind of any one having a fair knowledge of railways and of China.

Up to the present time the construction of railways in China has been carried on in a manner that might make a subject for a romance. Soon after the destruction of the Woosung Railway some Chinese officials, of whom the late Tong King Sing was the real moving spirit, decided to open coal mines in the neighbourhood of Kaiping, about eighty miles from Tientsin. Mr. Claude Kinder, who had had experience as a civil engineer in Russia, and also on the railways in Japan, was appointed assistant engineer, and a few years afterwards, on the death of his senior, he became, first, acting, and then actual, engineer-in-chief.

Luckily, Mr. Kinder was a man of broad views, of indomitable perseverance, and, to judge from all he has come through, with the hide of a hippopotamus. The mining installations had been started on modern principles and on a considerable scale, and a tramway, which, with a clear perception of future developments, was of the standard gauge, was constructed to the nearest navigable waters.

Mr. Kinder, as chief, continued the work he had commenced as assistant, and out of materials at his disposal constructed a little locomotive engine. As soon as this was known at headquarters he was ordered to stop using it and to employ ponies or mules. Bringing it out occasionally, however, to assist when traffic was heavy, he soon increased the output so greatly that mechanical traction became a necessity, and reluctant permission was given to order a locomotive from abroad. He was still forbidden to carry passengers, but by degrees the line had to be extended to a better shipping place at a greater distance. He could not refuse to allow a wayfarer occasionally to get into an empty truck, and it would have been inhuman in severe weather to refuse him a little shelter, and so with a perseverance as astonishing as it was praiseworthy, he managed, little by little, to bring about such a state of affairs that the company found they were running

WHAMPOA DOCK AT CANTON

a passenger service free of charge. The thing had been done so gradually and it had got so firm a hold before its existence was recognised by the officials, that it could not be stopped, and nothing was left for them to do but to charge fares. After years of persistent work it was agreed that the line might be continued to Tientsin via Tong Ku, close to Taku, at the mouth of the Peiho. The station at Tientsin was on the opposite side of the river to the settlement, and, after difficult negotiations, permission was granted to build an iron bridge to facilitate the passage of passengers and goods. Mr. Kinder, having gone home for a short holiday, the local authorities destroyed the scarce completed bridge, and to this day, a period of about ten years, it has not been rebuilt, and passengers and their luggage are taken across the river in small, open boats.

It was subsequently decided to extend the railway to Peking, but it was decreed that it must stop some miles outside the wall, with the result that the worst part of a journey from London to Peking was the hour and a half in that infernal vehicle, the Peking cart, from the station to the residential part of the capital. The traffic on this line is sc large that, although the road has been opened scarcely three years, the business has been nearly doubled. To meet this growth the officials have permitted an electric tramway (which the writer has not yet seen) to be built to the gate of Peking, thus necessitating a change of carriages at the station and again at the gate, though there would be no difficulty in continuing the railway line not only up to the gate, but well into the Chinese city.

A PROMINENT CHINESE FAMILY GROUP AT CANTON

Here, again, it may be said that the writer is giving history instead of writing of the future, but what better guide can one have to the future than a survey of the immediate past? And in this case the writer is telling not of what took place in the Middle Ages or even at the date of the ill-fated Woosung Railway, but of what is taking place to-day in the case of a railway built by Chinese officials with Chinese public money, and in the success of which, according to all our ideas of human nature, they ought to be deeply interested; but, regardless of the experience of foreign countries,

blind to the fact that where stations have been placed in unsuitable localities, extensions have afterwards had to be carried out at incalculable cost, turning a deaf ear to every argument, they seem to have decided that, having given a grudging permission to the railway department to build the line, it is now their duty, as patriotic statesmen, to put every obstacle in the way of its proving a success and to do everything which will neutralise the good effects which might have been produced.

Some of them may, perchance, even nourish the belief that by so doing they may make the scheme a failure. Luckily, that is impossible, but they can retard the advance of their country to an extent which is perfectly appalling. It is on a par with their other proceedings that the city gates are still closed at sundown, and if a train arrives after that hour the passengers have to pass the night in dirty hovels outside the wall.

The civil engineer relying on himself has a very poor chance in such a country. The only people who have any chance of holding their own are strong corporations, and they, no doubt, will give openings for the employment of capital as well as provide posts for a fair number of engineers. The manufacturers of locomotives, of rails, and of other accessories will likewise derive some benefit. The process of advance will go on steadily and continuously, but the rate will probably not be such as to satisfy the wishes of all those who are looking Eastward.

And here the writer comes to another branch of the subject. The Chinese-owned railway referred to has been extended from Peking to Paoting Fu, in one direction, and to Shan Hai Kwan, near the end of the Great Wall, in the other direction, and is now being extended into Manchuria with money raised in London. In addition to this, a most important line, the one from Paoting Fu to Hankow, is being built by a Belgian syndicate. This has attracted much attention.

LI HUNG CHANG AND SUITE AT SHANGHAI

The British Government has been blamed for allowing a company which is not British to construct a railway into the valley of the Yangtse, and British merchants and capitalists have been blamed for allowing a line of such importance to slip through their fingers. It must, however, be remembered that British capitalists cannot be expected to take up a concession which does not

A NATIVE FIRE BRIGADE AT SHANGHAI

promise to give a suitable return. It may be said that this argument applies with equal force to the Belgians; but there is an idea, which the writer believes to be well founded, that the Belgians are in a position to agree to terms at all events of a more vague description than could be accepted by Englishmen. For one thing, most of the money is French, and that means that, in the case of any difficulty, they will have the support of the French Government, and while it is most distinctly stated that the Russians are in no way interested in the line, it is believed that in the case of the French Government taking up a claim, the Russians would give the Chinese to understand that the claim had better be conceded. It is needless to say that nothing of this sort can be expected from the British foreign office.

The writer is not here talking of unjust claims; he would not for a moment imply that the Belgians contemplate taking an unfair advantage of the Chinese, but in carrying out large undertakings in a country which is new to them, unforeseen difficulties are sure to arise for which no provision has been made, and the whole undertaking is viewed in such a light by the Chinese authorities that they are sure to propose arrangements which, while they do the Chinese no good, place great obstacles in the way of carrying the scheme to a successful issue. In such a case it is easy for the foreign office of any country to assist its people, and the French, Russian, and Belgian offices are much more ready to act than the British.

Every British resident in China is willing that his interests or those of the entire British community should be sacrificed if they conflict with imperial interests, but it is beyond one's comprehension to understand how it can be to the interest of the British Empire or how it can add to its prestige to make treaties with China, to keep a minister at Peking, and yet refuse to do its utmost to enforce claims which it believes to be just. It would please a British syndicate much better to make railways so that they would best suit their purpose and attract traffic, resulting in an income that would pay a good dividend and enable them to pay over a handsome bonus to the Chinese, than to make them subject to such obstructive conditions that they have to stipulate for privileges including a guarantee against

THE MARKET PLACE AT SHANGHAI

loss; but if these are the only conditions agreeable to the Chinese, then the Chinese should be made to adhere to the conditions which they themselves have imposed.

It is often argued that while statements are constantly made to the effect that merchants and others do not get sufficient support from the foreign office, still merchants do go to China and make money; claims are, on the whole, few and far between, and certainly the largest merchants are those who give least trouble, and that this makes it clear that the abuses of which so much is sometimes heard are more imaginary than real. The explanation is simple.

At the time of the original treaty with China import duties were fixed. These are moderate in amount and justly collected. Some people have taken the extensive ground that the working of the treaty is such as to free all import goods from all further taxation. The writer has never been able to adopt that view, because China must be left in a position to raise whatever revenue is necessary, but she has always considered that the import duty (of approximately 5 per cent ad valorem) freed the goods from all further special taxation on account of their origin, *i. e.*, they were entitled to all the privileges of native goods. Subsequently a tax was put on all goods moved inland. Permission was afterwards given to commute this for a single payment of half import duty, and, as a matter of fact, this was a fair compromise. It seems clear, then, that foreign goods, having paid import duty and half duty, should not be subject to any terminal or other tax in respect of their being foreign; still, as a matter of fact, taxes are demanded under various names, or the natives buying the goods are forced to pay irregular taxes on them. The extent to which this is carried on is almost inconceivable, and while the amount of the taxation is small and well within the proportion which the goods will stand, its irregularity tells very much on the individual trader and may well turn a profit into a loss, because the margin of profit is very small.

While, however, the irregularity is great in individual cases, merchants accustomed to the business can fairly estimate the amount on the average. They have come to China to make money, not to reform the collection of taxes, and, making an allowance for these irregular squeezes just as if they were regular, they carry on their business in a manner that proves satisfactory to all concerned, and the larger their business, the less these irregularities affect them. It is the smaller man who cannot make an average who really is the loser.

Under these circumstances the larger merchants have no inducement to complain. It is for them, on the whole, much better to be on good terms with every one and let affairs take their own course. And this leads to a very definite conclusion. While most of those who have visited China for a short time, and who have seen the glaring defects of the entire system of government, have suggested that the proper thing to do is to approach the government, point out the abuses, and suggest remedies, the writer is of the opinion that, as it has been in the past, so in the present and immediate future success is most likely to attend the efforts of those who are prepared to take China as it is.

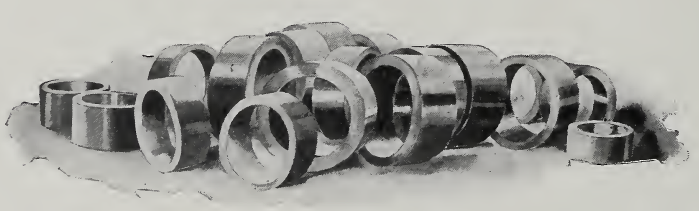
Setting to work to reform China is not a course that suggests itself as one advisable for a young man to adopt. The man who sees existing defects, who sees easy remedies, and spends his life in trying to get the Chinese to adopt them, does not, in the end, accomplish as much as one who takes things as they are and sets to work to carry on his business in a manner to fit in with the circumstances. Even in China things do move, though they move slowly, and continual contact with Europeans has a good effect on the oriental.

Mr. Kinder saw as well as any one twenty years ago that China required some thousands of miles of railways. He also knew that at that time, before the war with France, China might have had the command of vast sums of money on terms which any other country would have thought extremely easy, and he

believed, with justice, that the construction of a railway system was the only way to get rid of many of the abuses of the government and make China able to hold her proper place in the world. Still, if he had spent his time putting large schemes before the Chinese and trying to get them to adopt them, the result would have been utter failure. He would have done nothing for himself and nothing for China. Instead of this he set to work to build a locomotive with an old portable boiler and some wheels rescued from the scrap heap. The result,—about 300 miles of railway in twenty years,—may not seem very great for an empire like that of China, but it is better than nothing. It is the forerunner of the system now in progress, and is a work with which a man may well feel satisfied as the work of a lifetime.

The writer has hitherto referred principally to British undertakings, and only incidentally to the Belgian syndicate. If, however, Manchuria is to be included in China for the purposes of this article, some reference must be made to the Russians, who are carrying out railway and other works on a scale and at a speed that may well excite envy or admiration, according to the point from which it is viewed. That Russian power and prestige has advanced enormously in China of late is apparent to all, and most of us believe that it has been more or less at the expense of the British. Still, the presence of Russia, which is a progressive power, has many advantages, probably more advantages than drawbacks.

All who wish to succeed in China must be self-reliant,—they must trust as little as possible to government assistance, they must be prepared to accept the country as it is, and also its government, which, with all its defects, consists principally of men whose honest and patriotic belief is that European civilisation is unsuitable to their empire; whose habits can be altered only by slow degrees; and whose modes of action result in what to European eyes is obstructiveness of the most determined type. While China will for years to come provide a field for engineers and engineering enterprise, it is neither going to be opened up nor broken up with the speed that many people seem to expect.



THE DEVELOPMENT OF IRON MANUFACTURE IN THE UNITED STATES

SEVENTY-FIVE YEARS OF PROGRESS

By John Fritz

OF John Fritz it was very truly said in these pages on one occasion that, foremost as a worker in a field of industry in which progress during the past seventy odd years has been marvellous to a degree, and which, as a factor for good, has no rival,—the manufacture of iron and steel,—few men, now living, have had a longer or larger experience than he. A special interest is, therefore, obviously attached to whatever Mr. Fritz has to say on iron and steel, and, with his kind permission and that of the Franklin Institute, the following pages have been given up to practically the whole address which he delivered recently before that institution on the occasion of the celebration of its seventy-fifth anniversary. Mr. Fritz in this confined himself to some personal reminiscences of his connection with iron and steel making in the United States, and this fact alone lends a distinctive value to his remarks.—THE EDITOR.

This being the last year of the century that has done so much to change the face of society, and for the betterment of mankind, it will be interesting to take a brief retrospective view of the events that have taken place during this remarkable period, and in doing so we witness the most wonderful progress that has been made in the advancement of the arts of science and civilisation, all the effects of which are far-reaching.

In the very front we see the phenomenal progress that has been wrought in the various branches of manufacture in all parts of the civilised world. We look again and find that the manufacture of iron is in the lead, and that the United States comes in for a large share of this all-important branch of manufacturing industry, which is the advance guard of civilisation.

The first puddling furnace in the United States was built at Plumsock, on Redstone Creek, about midway between Connellsville and Brownsville, in Fayette County, Pa., in 1817. A flood caused the partial destruction of this mill. The machinery was subsequently removed to Brownsville. In 1819 a rolling mill was built at Pittsburgh in which there were four puddling furnaces. This mill was accidentally blown up, and permanently dismantled in 1829, and the machinery was taken to Covington, Ky. Both enterprises thus seem to have ended in disastrous failures.

About 1810 Isaac Pennock built a rolling mill (at that time called a "slitting mill," afterwards converted into a plate-mill) near Coatesville, in Chester County, Pa. In 1816 it came into the

hands of Dr. Charles Lukens, a son-in-law of Isaac Pennock, and was operated by him until his death in 1825. It was during this period and on this mill that the first boiler plate was rolled in the United States. The blooms were heated on a grate fire and the rolls were driven by an old-time undershot water-wheel. When a boy I heard the older men say that the mill was often short of power, and frequently all the workmen would run and get on the buckets and tread with them, in order to prevent a stall which would have caused fire cracks in the rolls, and, sooner or later, a broken roll. This being before the days of railroads, coal was hauled from Columbia, thirty-five miles distant, and the plates were teamed to Philadelphia, thirty-five miles away, and were shipped without being sheared. A notable circumstance about these works is the fact that they have always remained in the family of Isaac Pennock, and are now operated by his descendants of the fourth generation.

What I have thus far said will be sufficient to give some idea of the condition of the trade at that time, and will enable a better appreciation of the great improvements that afterwards were made.

From 1824 until 1836 but little progress was made in the way of marked improvements. During the thirties some puddling furnaces were built, to puddle run-out or refined pig metal, and eventually they got in the way of using some close grain pig iron in connection with the refined metal.

In the early forties puddling began to come into general use, but only close iron was used. In the years 1844-45 the manufacture of rails commenced. This at once gave puddling the leading position in the manufacture of iron, which it held until it was beaten by the Bessemer process.

About this time the manufacturers' trouble began. The demand for puddlers soon exceeded the supply, and they thought they ought to have things their own way. Up to this time the old-fashioned Welsh hammer was the only mode in use for putting the puddled ball in shape for the rolls. The hammerman or "shingler," as he was called at that time, was the king bee, and when he went wrong, as he frequently did, the puddlers had to quit work until such a time as Mr. "Shingler" was ready to go to work, which sometimes required several days; and when at work, woe be unto the puddler who might happen to be on bad terms with him.

The hammer striking a uniform blow, no coaxing could be done; consequently great skill was required during the first few strokes of the hammer to keep the ball in such shape that it could be edged and upended in order to get a good-shaped and compact bloom. Should the "shingler" fail in this, which he could and at times did, and that without any apparent intention, then a row was started which sometimes ended in fisticuffs.

The next improvement in this line was the introduction of what was known as the "crocodile" squeezer, which was entirely unlike the hammer in every way, and it was so easily worked that almost any of the puddlers could put their own work in shape; but, unfortunately for the manufacturer, they could coax a ball into shape that was not properly worked in the furnace. So, while this was entirely satisfactory to the puddler, it was very unsatisfactory and unprofitable to the manufacturer, with the result that there was constant bickering between the employers and employees, —a condition of affairs that should not exist.

Next came the "Burden" and "Winslow" squeezers; the latter was used for a time, but finally the "Burden" came into general use, and is to this day the most perfect machine for the purpose intended that has ever been devised, not alone on account of its simplicity in construction and the perfect manner in which it does its work, but because, also, it establishes justice between the ironmaster and the workmen from which there is no attempt to make an appeal. When a ball would break, the workman, without saying a word, gathered together the pieces and took them back to the furnace and

worked them into a proper condition, and in the end the squeezer proved to be the puddler's friend. Notwithstanding all its good qualities, its introduction caused strife in practically all the mills that introduced it down to about the year 1856. Some of the strikes were long and bitter, and many incidents might be recited in relation to its introduction, some amusing, some ridiculous, and others revengeful. However, soon after the system came into general use, an armistice was agreed upon, which finally resulted in a treaty of peace, which was advantageous to both parties.

In or about the year 1848, boiling came into general use. This was a great improvement, and puddling soon became the all-important branch of the great iron industry of the country, and continued in the lead until it was overtaken by the almost magical invention of Sir Henry Bessemer.

Until 1840 all the pig iron produced in the United States was made with charcoal. My first connection with a furnace dates from 1839. It was driven by water, a wooden blowing-cylinder being connected with a crank by a wooden beam. Neither of the journals of the water-wheel shaft were turned off, but were put to work just as they came out of the sand. The furnace was blown by an open tuyere. The whole plant was of the crudest construction. The weekly make was about sixteen to twenty tons. It was placed against a bank, level with the tunnel head, so as to avoid hoisting the material up. This was about the character of the furnaces in general use at that time.

I was sent there as a "cub" to put up a belly-pipe which was made at the shop in which I was learning my trade. When it was put in place it was, as I remember, about six or eight inches too short, and I supposed somebody had made a mistake in the length. The founder was a consequential-looking man, and quite stout, with a blue flannel shirt and his "pants" held up by a rather broad leather band buckled around his body, somewhat in the order of many we see to-day, but was not gotten up in the same style. He said rather brusquely that "it was all right." The pipe was connected at the rear end to the main pipe by a short leather connection, which I was told was to allow the belly-pipe to swing out of the way so that they could get the cinder out when the furnace was not working well.

This was the general condition of the furnaces until 1840, when Mr. David Thomas, since affectionately called "Father Thomas," made the first anthracite iron in a commercial way that was made in the United States, and marked the commencement in this country of the phenomenal development of the blast-furnace practice that has taken place in the latter part of this century.

We left the rolling mills in 1824 in a very crude condition, and there was no marked improvement in them until the manufacture of rails commenced, which, as already mentioned, was about 1844. But even at this time the plans of the mill and manner of building practically remained the same, being geared, and it seemed to me that the general impression amongst the rolling mill proprietors was that the more wheels they could get in, the better was the mill. Up to that time the carpenter or millwright had largely the say; consequently wood was much used. The shafts were generally made square, and the fly-wheel and gear-wheels were secured on them by the use of wooden wedges, into which other thin wedges of iron were driven. No matter if the foundation was built of wood or stone, a large piece of timber was placed on top, to which the housings were secured, the idea being that it was essential that the train should have some elasticity in order to take the shock off the machinery, thereby preventing breakage.

After the manufacture of rails commenced in 1844, more rigid and better workmanship was required. The mills, as heretofore, were all geared, but the carpenter and millwright were superseded by the machinist. The shafts were now turned up, wheels were bored out, and the mill was generally fitted up in a more workmanlike manner.

From 1845 to 1856 but few improve-

ments were made, either in machinery or the manner of rolling, except the introduction of the rail-straightening machine which took the place of the sixty-pound sledge and a special man to handle it. When he wanted a rest, the works had to come to a standstill until such a time as he was completely rested, sobered up, or restored to health, as the case might be.

The year 1857 is a memorable one in the history of the manufacture of iron. As before stated, in 1844 the forge carpenter and millwright were superseded by the machinist, who now comes to the front as a mechanical engineer, not full fledged, but with an amount of knowledge gained by experience which qualified him for the important duty which awaited him. Down to this time all the rails were rolled on a two-high train, the pile being passed back over the top roll, which meant a great waste of time and loss of heat. When the flanges once began to crack, which was one of the serious troubles, being all the time rolled in one direction, it greatly aggravated the difficulty. The result was that when an imperfection occurred in a flange, the trouble increased with each pass through the rolls, and so extended that it was a common occurrence for a flange to tear off the whole length of a rail and wind around the roll, forming what, in rolling mill parlance, was called a collar, which very generally ended in breaking some part of the train and often the roll.

The iron was frequently both red- and cold-short and all other shorts, and in addition to this would stand but little heat; consequently the end of the pile which entered the roll first would split and open out like the mouth of an alligator. Then, of course, it would not enter the rolls without force, which was applied with the buggy, using it as a battering-ram. After making several vain attempts to get it to enter the rolls it very frequently had to be turned end for end. The loss of time and heat taken up in going through all this was such that it was almost an impossibility to get a perfect rail. Had it not been for the use of putty, oxide of iron and the absence of inspectors, few rails would have been shipped.

In order to get over the difficulty of the flanges tearing off we went to quite an expense. Some iron of a better quality was used for the flanges, which, in a measure, gave some relief in that direction. But the iron being much stronger than that in the body of the pile, required more heat and greatly increased the difficulty of opening the end of the pile in the first few passes. We were now in a sad dilemma, and something had to be done. I was sick at heart, and had it been manly I would have run away.

But, during all this time, I was giving the subject much consideration, and had fully made up my mind that, if a three-high mill could be made to work, the difficulties could all be overcome. Besides, I had made up my mind that it was the only proper way to roll iron. I was now prepared to suggest the building of a three-high mill, which I did, and the suggestion was met with a rebuff, which was not unexpected. The objectors said, in substance:—"It was a visionary scheme; it had never been done, and had it been practical it would have been done long ago." In reply, I told them something must be done or there would be a large funeral, and I did not want to be one of the mourners. The subject was then more seriously taken up by the company, and it was suggested that a better ore should be secured as a mixture to improve the quality of the iron; but the location of the works was such that, with the transportation facilities then available, a suitable ore could not be got at a price that would permit it to be used as a rail mixture; so this course was abandoned.

The company now began to see that it was necessary that something should be done. The directors called a meeting, and, after consultation with some practical iron men, decided to put up a geared two-high mill, and by greatly increasing the speed of the rolls, the rail would be finished in much less time, and consequently at a higher heat, which would prevent the serious trouble of

rough and torn flanges. After some discussion, I was ordered to build a new mill, two-high, geared. As my patience had become exhausted, and being thoroughly disgusted, and especially so with the geared mill, I most emphatically said I would not do it, as two of the most objectionable features of the present system would still be retained. I was then asked what right I had to dictate to the company in regard to the policy they should pursue in the line of their business. I answered that I had no right whatever, being thoroughly convinced that a two-high mill would not remove the difficulty, and in the end would be a failure and the result financial disaster. Being a young man and the only capita' I had in the world being my reputation, and that being quite limited, I did not purpose placing it in danger where the chances were so unequal. This interview ended in a suspension of hostilities, and for a short time nothing was said on either side. But the trouble in the mill still continued, and something must be done and quickly. Having already lost my reputation for complaisance and being considered as the most arbitrary of men they had ever met, I concluded that I would do as I had been compelled to do before and many times since,—assume authority and go ahead with the three-high mill, which I did, and commenced work on the patterns. The drawings had already been practically completed.

After the pattern for the housing was well advanced, Mr. E. Y. Townsend, the vice-president, came out to the works, and I informed him of what I was doing, and again talked the situation over with him. He said nothing, but thought it proper to let the company know what was being done, to which I assented. In about a week, as I remember, he came to the works again. This time he was armed with a legal document opposing the spending of the money in the way it was being done. He handed me the document to read, which I did. I then handed it back to him and said nothing. He then asked me what I thought about it and the best course to pursue. In answer, I said:—" You know the troubles we have had, and it is useless to go over them again, and you know my opinion, which is irrevocable." After some friendly talk on the condition and the importance of the change proposed, he said, " Go ahead and build the mill as you want it." I asked, " Do you say that officially?" to which he replied, " I will make it official." And he did so.

When I look back to that eventful interview, which took place on a Sunday morning long years ago, and recall to mind Mr. Townsend and myself, with evidences of failure on all sides, and surrounded by the gloom of future uncertainties, I cannot but feel it was the most critical period not only in my own career, but also in that of the Cambria Iron Company,—the one with which I was connected. And here I wish to say that to Mr. Townsend belongs the credit not only of the introduction of the three-high rolls, but also for a large share of the subsequent marvellous prosperity of the Cambria Iron Company, which followed the introduction of the three-high mill and its many accompanying improvements.

The opposition to the three-high mill now came in from all quarters. The heaters on the rail mill were unanimous in their condemnation, and waited on the company to tell them what a direful failure it would be. Next I had to meet the combined prejudice of the iron-masters, who were a power at that time. Some of them would tell the managers that the whole thing was certain to be a failure. Next came my friends, in the trade and out of it, begging me to abandon what would surely prove a failure and blast my reputation for life. One of my dearest friends, with whom I had been employed for a number of years, came to see me, and, if possible, to get me to change my plans. To them all I said, " No, I can make it work, and it is the only plan that can be adopted that will save the company."

After all these years there is no person other than myself who can fully appreciate the trying position in which the

managers were. On the one hand, I was to build a mill on an untried plan, and absolutely refusing to build the mill they asked for, knowing full well that it would remedy the trouble only in a small degree, and that the money spent on such a plant would be thrown away. On the other hand, there was a strong party of stockholders, protesting in the most positive manner against going on with my plans, and notifying the managers that they would hold them personally liable for all the loss and damage that might grow out of their unwise action, as they considered this action to be, in adopting a new and untried method that was against all practice in this and the old country, for at that time we were expected to be followers instead of leaders.

Notwithstanding all the opposition and trouble we had to encounter, the work on the mill was being pushed along as fast as it was possible. But there were many difficulties in the way. The most serious was the want of proper tools and facilities for doing the work. Many makeshifts had to be improvised, which all required time and labour. During all this time much talk and speculation were going on in regard to the final result, to all of which I gave but little attention.

At length the mill was completed, and on the third day of July, 1857, the old mill was shut down for the last time. On the fifth we commenced tearing the old mill out, as the new one had to be put in the same place. The work was pushed as fast as possible, day and night; but, as it was before the days of electric light, the night work could not be done with the same expedition as to-day. At the same time everything in the rail department was remodelled and the floor line of the mill was raised two feet. On the 29th of the same month everything was completed and the mill ready to start. The starting of the mill was the crucial period.

No invitations were sent out. As the heaters, to a man, were opposed to the new kind of mill, we did not want them about at the start. We, however, secured one of the most reasonable of them to heat the piles for a trial. We had kept the furnace hot for several days as a blind. Everything being ready, we charged six piles. About 10 o'clock in the morning the first pile was drawn out of the furnace and went through the rolls without a hitch, making a perfect rail. You may imagine what my feelings were as I looked upon that first and perfect rail ever made on a three-high train; and you may know, in part, how grateful I felt toward the few faithful men who were about me, and who had stood by me during all my trials and difficulties. Among these were Alexander Hamilton, the superintendent of the mill, and Thomas Lapsley, who had charge of the rail department, William Canam and my brother George, all of whom have gone to their reward.

We now proceeded to roll the other five piles. When two more perfect rails had been rolled, we were obliged to stop the engine for the reason that we were so intently watching the rolls that the engine had been neglected, and, being new, the eccentric strap got hot and bent the eccentric rod so much that the engine could no longer be worked. As it would have taken some time to straighten the rod and reset the valves, the remaining piles were hauled out from the furnace onto the mill floor. About this time the heaters, hearing and seeing the exhaust of the engine, came into the mill in a body from the opposite end of the mill to where the rails were. Seeing the unrolled piles lying on the floor, they took it for granted that the new train was a failure: and their remarks about it were far from being complimentary. Mr. Hamilton, coming up and hearing what they were saying about the mill, turned around, and using language more pointed than polite, told them if they would go to the other end of the mill they would see three handsomer rails than had ever been made in their country, Wales. After getting the engine in shape, the day being Friday, we ran all day, and at night put the regular night turn on.

Everything worked well up to noon on Saturday, it being our custom to

stop rolling at that time. About six o'clock in the evening Mr. Hamilton and myself left the mill, and on our way home congratulated ourselves on the fact that our long line of troubles and disappointments was now over. About an hour later I heard the fire-alarm whistle blow, and rushing back to the mill, found it one mass of flames from end to end. In less than one hour's time the whole building was burned to the ground, and a story was started that the new mill was a failure, and that we had burned the mill to hide our blundering mistakes. The situation of affairs on that Saturday night was such as might appall the stoutest heart. The product of our labours and anxieties lay there, a mass of black and smoking ruins, and the money that had been so hard to get with which to build the mill was gone. The prospect was, indeed, gloomy, but there was one gleam of light amid all the darkness; and that, the pile of perfect and new rails, which, as Mr. Hamilton had said, had never been beaten in Wales, from which country the greater part of the rails used at that time came. Above all, the mill had been tried and found to work magnificently, and it was these two facts that gave us all fresh courage, and enabled us to rebuild the mill.

The next day being Sunday, it was devoted to rest and to thinking over the matter. On Monday morning we commenced to clear up the wreck, all the workmen giving a full day towards it, and began the work of rebuilding. In four weeks from that time the mill was running, and made 30,000 tons of rails without a hitch or break of any kind, thus making the Cambria Iron Company a great financial success, and giving them a rail plant far in advance of any other plant in existence. This position they held, unquestioned, both for quality and quantity, until the revolutionary invention of Sir Henry Bessemer came into general use.

In the construction of the three-high mill there were many changes and improvements on the old two-high mill. Up to that time the leading spindles had a groove cut in them to weaken them, so that if any extra strain should come on the rolls, they would break instead of the roll; and the couplings were made light so as to act as a kind of safety-valve. Then there was a breaking box placed between the screw and the roll. If there was not one of these safety devices breaking each day, the pattern was made lighter. The result was that some of them were breaking several times daily, furnishing a constant source of annoyance. In building the new mill they were all made so strong that they were not calculated to break. The breaking box on top of the roll was made solid, as they were apt, when they gave way, to break the collars on the rolls, which should, if possible, be avoided. All these changes were stoutly opposed by the foremen and workmen of the mill.

A few days before the mill was ready to start, the superintendent of the mill discovered that the breaking box was solid; he then got the pattern and took it to Mr. Lewis, the pattern-maker, and told him there was a mistake, that it was made solid. Mr. Lewis told him that it was made as the old man had ordered it, to which the superintendent said, "The old man has gone crazy." He looked me up and wanted to know if I had ordered the breaking box for the new train solid. I said, "Yes;" and he replied that if, with solid spindles, heavy coupling boxes and solid breaking boxes on top of the rolls, a piece should enter a wrong groove, or a collar should form on the rolls, which was sure to take place, the mill would be broken to pieces. To this I replied:—"I would rather have a grand old smash-up once in a while than be continually breaking something and keeping the mill standing half the time and the metal wasting in the furnace." He said:—"Well, you will get it, sure;" but we did not, and, as before stated, the mill made 30,000 tons of rails without a break of any kind, which, at that time, on iron, was nearly a year's work.

The heating furnaces were rebuilt, making them larger, the roofs much higher, and the length of the furnace greatly increased, which about doubled

the work that had previously been done. A number of improvements were also made on the train to facilitate the work and make it much easier for the men. Among them was the introduction of the driven feed-roller, out of which, later on, came the blooming table, which is now indispensable in the rolling of steel ingots, either on a three-high or reversing mill.

In 1864 the Bessemer process was introduced in the United States. Its introduction and perfection will ever remain one of the most interesting epochs in the history of the iron business. As already stated, the forge carpenter and millwright were superseded by the machinist. Immediately after the introduction of the three-high mill all the rail mills in the country were changed, and all the new ones that were built adopted the same plan. In fact, Mr. B. F. Jones, one of the oldest, one of the leading, and one of the most practical and successful ironmasters in the country, and one of the very first to see the advantages of the system, said to me a short time since, that it was the commencement of the great improvement which took place in the iron works after 1857 which paved the way for the introduction of the phenomenal Bessemer process, which, as the Hon. Abram S. Hewitt says, takes its rank with the great events which have changed the face of society since the time of the Middle Ages.

At this time the machinists before alluded to were called to the front to brave the danger and fight the great battles that have ever to be encountered in the introduction of new metallurgical processes, and in none were the difficulties more alarming and disheartening than in the Bessemer process. These men had received a training which eminently fitted them for the duties they were called upon to perform. Having been inured to hard work, they entered into this new field with such an amount of energy and determination that it made failure impossible.

In witnessing the beautiful and interesting but simple process of blowing a heat of metal, and the regularity with which it is done at this time, and the quantity turned out, it is impossible for one wholly unacquainted with its early history to even in a measure realise the fear and anxiety of those who were responsible for the result. When a charge of metal was poured into the vessel anxiety commenced, and as the heat increased, anxiety increased in a corresponding ratio, until both became intense. It was when the heat was greatest that accidents were most likely to happen. The refractory material with which the converters were lined, especially the bottoms, would become plastic, and when in that condition the effect of the heat and the blast would waste the tuyeres and bottoms away so rapidly that from one to three heats were all we could get off of one bottom. Frequently they would give out at the first heat; then out would come the metal through the bottom; and having to use much water about the converter, the place under the vessel was at all times wet, and the result was explosions, often very dangerous, as the hot metal was blown in all directions, frequently inflicting serious injuries on the workmen, a calamity greatly dreaded and the cause of the gravest anxiety to those in charge.

When an accident would occur anywhere about the works the first question asked would be:—" Is any one hurt ? " If not, we would go to work at once to repair, with that object only in mind. If, on the contrary, some of the workmen were killed or seriously injured, it was impossible to describe the distress of mind that the person in charge had to endure. The anxiety one had when the charge was put in the vessel was increased with the heat until the heat was blown; but it did not end with the blowing of the heat. When the vessel was turned down it sometimes went too far and some of the metal ran out, resulting frequently in a grand pyrotechnic display of an exceedingly dangerous character. The next operation was to get the metal in the ladle, which was generally not a very difficult one, but it would frequently burn through the ladle, and then the only thing that could be done was to let it run into the pit and

order all hands out of the way, for fear of an explosion. As soon as the metal was set, all hands commenced to clean the pit, which was no easy task. Here were eight tons of molten steel in the pit burned fast to ingot moulds, bottom and sides of the pit, and to everything that would not burn up. If we were so fortunate as to get the ladle over the pit in good shape our anxiety was not yet at an end. It quite frequently happened that the stopper would pull off the end of the rod; then we had to use what we called a pricker to open the nozzle from the bottom. If the metal happened to be cold, which at that time it was apt to be, the nozzle would freeze up, as we called it; then the metal would have to be poured out of the top of the ladle into the mould, cinder and steel all together, with the result that generally the most of it got into the pit; then, again, if we escaped an explosion, we still had a mess in the pit.

Altogether, the difficulties we encountered were enough to appall the bravest hearts. My brother George once said, when at Cambria, that he did not believe there was a man who ever went into the Bessemer business, and was responsible for the result, who did not at times wish he had never gone into it; and so far as my experience goes I can fully verify it. And, further, I think that, if it had not been for the interesting and exciting character of the business, but few men would have been willing to endure the trouble and anxiety and to endure the physical labour and danger to which he and the workmen were constantly exposed, long enough to have placed the business on a commercial basis.

Having alluded to the trouble we had with the converter tuyeres which caused so much anxiety and loss of time, I will explain how we got over the difficulty at once. We were getting only from two to four heats off a bottom and then would have to turn the vessel down and put in tuyeres during the blow. It so happened that, at a time when we were having more than the usual trouble, the vessel was turned down and we were putting in two tuyeres when I was sent for, to go to the blast furnace, there being trouble there. As soon as the vessel was turned up I started for the furnace, not in the serenest state of mind. On my way over I was thinking over some new device for making the bottoms so that they could be burned in order to make them harder and better able to resist the action of the blast, as I had been thinking that that was one of the troubles. As I went into the furnace I noticed some firebricks about 5 inches square and 16 inches in length, such as are used in blast-furnace lining. At once I ordered some of them sent over to the converting department, and as soon as I could I went over and had them placed on end in the bottom between the tuyeres and well rammed in with ganister, put in the oven and well dried and put in the vessel. Result:—Twelve heats with one bottom.

From this time our troubles began to diminish, and instead of making only ten and twelve heats per day we soon ran up to fifty and sixty heats in twelve hours, and some of the works are now making seventy and eighty. This system of making bottoms was at once generally adopted, and is still in use.

I shall now return to the rolling mill. As already stated, with the introduction of the three-high mill in 1857, the commencement of the great improvement in rolling mills and machinery connected with them took place. The rolls were made larger in diameter, better fitted up, and a more powerful and a much better class of engines was introduced, larger and better heating furnaces were built, and many labour-saving devices were introduced. But with the marvellously increased production of Bessemer steel it was evident that a larger ingot must be used in order to prevent congestion in the pit furnaces and rolls. This, of course, involved the building of larger, heavier and more rapid working machinery.

In 1868 the lamented Holley, who, later on, became the consulting engineer of the Bessemer works and so remained until his death, and to whom America is largely indebted for the introduction of the Bessemer process and

for many improvements and important suggestions in the art, built a three-high blooming mill at Troy, N. Y. This mill had the top and bottom rolls stationary, the middle roll being moved up and down, to suit the work, by four screws passing through the bearing carrying the rolls. In the bearing there was a thread corresponding to the thread on the screws, which screws were driven by power. Holley also had lifting tables, front and back, fitted with loose rolls, and the ingots were pushed into the rolls by hand both in front and in back.

In 1871 my brother George, then superintendent of the Cambria Works, built a three-high blooming mill in which the middle roll was stationary and the top and bottom ones movable, with feed tables both front and back, and the rollers driven by power taken from the train. He also introduced what is called a "pusher" to adjust the ingot in a proper position on the table and also an arrangement for moving the ingot on the table in proper position to enter the rolls.

In 1872 we built at Bethlehem, Pa., a three-high mill in which all the rolls were fixed, with tables similar to those at Cambria, but driven by an independent power which very much simplified the arrangement of driving the tables. This is the plan of mill that was generally adopted, and for a moderate sized ingot and quick working is probably the best plan of mill. But for heavy ingots and for variety of work the reversing mills are preferable.

The rail trains are, with two exceptions, three-high, with larger rolls, very heavy housings and fittings, and more powerful engines, and generally have some kind of labour-saving device attached to the rolls. In fact, all the modern rail mills have introduced labour-saving machinery to such an extent that there is, comparatively speaking, but little left for man to do. This is, to a great extent, due to the introduction of steel, as it rarely either splits or cracks in rolling, while iron is ever liable to do both, which renders the use of delicate automatic machinery more difficult in rolling iron than in rolling steel.

Many instructive, annoying, and amusing incidents which might be related occurred in connection with the almost magical developments which took place in the manufacture of iron and steel during my long association with the business. But space will not permit it.

We left the blast furnaces in 1840, which, as before mentioned, was the commencement of the use of mineral coal, from which period the greatly increased production commenced. While there was no practical change in the principle of making pig iron, yet the continued increase in size of the furnace, the increased pressure and quantity of blast, the introduction of the Whitwell system of firebrick stoves, the better understanding of furnace working, the increased knowledge of the chemistry of pig-iron making,—all these, coupled with the indefatigable determination of the men in charge, contributed to bring about the unprecedented and phenomenal production which has so amazed the iron makers of the world.

In 1868 the manufacture of acid open-hearth steel commenced; but its progress was slow, and following the Bessemer, this process not being so interesting and exciting, did not command the attention and respect to which it was entitled. The fact that the Bessemer process was in the lead and the machinery was already in use, and that the knowledge of refractory material and the handling of the steel was already acquired, made the introduction of the open-hearth process easy compared to the Bessemer. But the fact that it made its way into general use quietly does not in any way detract from its great usefulness, and, with the invention and introduction of the Thomas basic process and its application to the Siemens-Martin open-hearth system, it takes rank only second to the Bessemer process as one of the greatest metallurgical inventions of the age. And taking into consideration the character of our ores and coal, and their geographical location, the superiority of the metal produced by

this process, for structural and machine purposes, may cause it, in the near future, to outrank the Bessemer in value and general usefulness.

When we look back to the commencement of the last half of the present century, and take a thoughtful survey of all the inventions and improvements that have taken place in the arts of metallurgy during this period, the complete reversal of the position that iron and steel formerly held in relation to each other, the superiority of steel over iron in the useful arts, and the immensely increased production which is unparalleled in the history of metallurgy, it seems impossible to fully realise that so great a change could have taken place within so brief a time.

While we have properly received great credit for the unprecedented developments we have made in the iron and steel industry in the United States, we must not forget that it was the inventions of Cort, of Mushet, of Bessemer, of Siemens, and of Thomas that enabled us to accomplish such important results; and to them all civilised nations owe a debt of gratitude for the incomparable blessing their inventions have conferred on society.

Yet how few of us even for a moment think of the trials, troubles, disappointments, mental anxiety and bodily toil these men had to undergo in the perfection and introduction of their inventions, besides suffering the sneers and jibes of those who imagine that an inventor is nothing but a wild enthusiast, and treat him accordingly. The story of many inventors is truly pathetic, and none more so than that of the lamented Thomas. The personal side of the story of the inventor of the basic process can only be appreciated by the reading of his life.

It should not be forgotten that Great Britain is the birthplace and home of the Iron and Steel Institute, and much of our success is due to the information we have gained from the invaluable papers read at their meetings and the discussions that followed them. Here I wish to say that I would commit an act of ingratitude should I fail to give credit to the brave and noble workmen who, throughout my long connection with the business, have ever stood ready to meet an emergency, no matter what the danger or difficulty might be. All that needed to be said was, "Come, boys," but never "Go, boys," and if the difficulties were not insurmountable they were sure to be overcome; and too much credit cannot be given to these fearless and energetic men for the almost fabulous progress that has been made in the manufacture of iron and steel in this country.

When I look back to my early days in the iron business long, long ago, probably too long, it brings to mind one of the happiest periods of my life. After my daily labour was done, I was free from all care until the next morning. After supper, at half-past six, then a simple meal, I returned to the works and helped the puddler, heater or roller, as the case might be, until about 10 o'clock. At that time the practical men, puddlers, heaters and rollers, were generally Englishmen and Welshmen. After the heats were charged in the furnaces, and while waiting for the charges to become heated, they would get their pipe,—"cutty" they called it,—and sit down on a pile of pig or puddled iron, as happened to be most convenient, and take their smoke. Having gained their confidence, I would take a seat by them and then they would tell me about the works in England, and describe how their mills were arranged, their system of rolling, the principle and construction of their puddling and heating furnaces, and how to work them. As I spent my nights in assisting them to puddle, heat and roll, I gained a very general practical knowledge of the manufacture of wrought iron, which soon became of great value to me; and to the nights spent in the works with these hearty and generous workmen I owe much of whatever success I may have attained in after life. The kind and generous manner in which I was always treated by them will ever have a green spot in my memory.

How little do the younger men that now have charge of our great iron and

PRODUCTION OF PIG IRON, STEEL INGOTS AND CASTINGS, AND FINISHED IRON AND STEEL IN THE UNITED STATES FROM 1890 TO 1898, INCLUSIVE.

Years.	Pig Iron. Gross Tons.	Bessemer Steel Ingots and Castings. Gross Tons.	Open Hearth Steel Ingots and Castings. Gross Tons.	Total Steel, Ingots and Castings, Including Crucible. Gross Tons.	Finished Rolled Iron and Steel, All Kinds. Gross Tons.
1890	9,202,703	3,688,871	513,232	4,277,071	6,022,875
1891	8,279,870	3,247,417	579,753	3,904,240	5,390,963
1892	9,157,000	4,168,435	669,889	4,927,581	6,165,814
1893	7,124,502	3,215,686	737,890	4,019,995	4,975,685
1894	6,657,388	3,571,313	784,936	4,412,032	4,642,211
1895	9,446,308	4,909,128	1,137,182	6,114,834	6,189,574
1896	8,623,127	3,919,906	1,298,700	5,281,689	5,515,841
1897	9,652,680	5,475,315	1,608,671	7,156,057	7,001,728
1898	11,773,934	6,609,017	2,230,292	8,932,857	8,513,370

steel industries know or even think of the severe mental strain, the great amount of bodily toil, the vexation, the surprises, and the disappointments that had to be endured by the men in charge during the erection and perfection of these vast establishments that are now engaged in the manufacture of iron and steel. This great work was not accomplished by command, but by example. It was the men in training, before alluded to, who erected, perfected, and put in operation these most marvellous enterprises of the age. And to these noble, brave and energetic men the people of the United States owe a debt of gratitude for the far-reaching results they so thoroughly accomplished, and which have already changed the social condition of the vast American territory. They have furnished us with a material which for quality and cheapness and quantity in a given time is without parallel, and could not have been realised by any other known methods. Without it the building of trans-continental railways would have been almost impossible. Had the rails been made in the old way out of the puddled iron, with the increased traffic on the Atlantic ends of the lines they would be worn out before the Pacific coast could have been reached. The credit does not end here. The reduction of freight rates, owing to the general use of steel rails, is so enormous that it has been intimated by one of the most distinguished public men that the saving alone on the cost of transportation due to the use of steel in the place of iron would, if available, amount to a sum sufficient to pay the American national debt in a comparatively short time.

In addition to the use of steel for rails, the Great West of the United States is being fenced with steel at a cost that seems almost fabulously cheap, and this product is being used largely for many other purposes. It was formerly iron that was used for structural work; now it is steel, and it has practically superseded the use of wrought iron. Steel is largely used in the construction of all grades of machinery employed in the manufacturing arts. It is the base of our immense inland system of transportation. It is this imperial metal that has enabled the engineer to perform the many daring and remarkable engineering feats of the last half of the century; without it they would have been practically impossible. It is the material used in the construction of the monster floating palaces that cross the ocean with the regularity of railway trains.

TOTAL PRODUCTION OF PIG IRON IN THE UNITED STATES FROM 1810 TO 1898

Year.	Long Tons.	Year.	Long Tons.
1810	53,908	1874	2,401,362
1820	20,000	1875	1,023,733
1830	165,000	1876	1,868,961
1840	286,903	1877	1,066,594
1850	563,755	1878	2,301,215
1854	657,337	1879	2,741,853
1855	700,159	1880	3,835,191
1856	788,515	1881	4,144,254
1857	712,640	1882	4,623,323
1858	629,548	1883	4,595,510
1859	750,560	1884	4,097,868
1860	821,223	1885	4,044,526
1861	653,164	1886	5,683,329
1862	703,270	1887	6,417,148
1863	846,075	1888	6,489,738
1864	1,014,282	1889	7,603,642
1865	831,770	1890	9,202,703
1866	1,205,663	1891	8,279,870
1867	1,305,023	1892	9,157,000
1868	1,431,250	1893	7,124,502
1869	1,711,287	1894	6,657,388
1870	1,665,179	1895	9,446,308
1871	1,706,793	1896	8,623,127
1872	2,548,713	1897	9,652,680
1873	2,560,963	1898	11,773,934

Fifty years ago steel was a luxury to the engineer. Modern practice of steel-making, in the hands of the mechanical engineer, the metallurgist, and the

chemist, has wrought wonders in producing a material which is used alike in the manufacture of articles of the most weighty, the rudest and cheapest grades, and in the construction of the most intricate, the finest and most delicate implements and machinery. And it is boldly asserting its value and importance through every walk of modern life.

In concluding these reminiscences it may be interesting to refer to the statistics on the opposite page, compiled by the American Iron and Steel Association. These show the wonderful progress that American iron and steel industries have made since 1840, when I started out to learn my trade as a blacksmith and machinist.

PRINCIPLES OF ARRANGEMENT IN MACHINE SHOPS

THEIR BEARING UPON ECONOMIC PRODUCTION

By Frederick Remsen Hutton

IT will be recalled that, something over ten years ago, Mr. Edward Bellamy presented a study of economic problems, under the title of "Looking Backward." It is unfortunate that in this masterly presentation there should have been gathered together so many new ideas as to have stood in the way of a general acceptance of several very sound principles which the author had conceived. Among these was the wastefulness of certain present methods of distribution and the extravagance which forced upon the consumer the expenditure of supporting a large number of middlemen or distributers.

It would appear to be to the economic advantage of a nation or community that as great a number as possible should be earning their livelihood by direct production of wealth, and as small a number as compatible with the best conditions of civilisation should be engaged in rendering what the economists call "personal service" to the producers. It is in recognition of the soundness of this principle on the economic side that the great American department stores have come to the front, and it is in further recognition of it that the author has commended the tendency of American production to do away with the consulting engineer as an employee of the buyer, which has been the accepted British policy and the early American method. American advancement along manufacturing lines with the high price of productive labour has been greatly helped by a tacit recognition that the best results would be attained when the expert skill of the consulting engineer was rendered directly to the producer, and chargeable to his price for the product, rather than that the expense for such service should be a charge upon the wealth of the country already in existence in the hands of the buyers. In this view, which seems to the writer to be a sound one, the mechanical engineer of the twentieth century is to be largely a manufacturing engineer, and the problems of economic production are to be of special importance to such persons. This idea has its bearing in education also, in a sense which is both deep and far-reaching.

The productive shop, being a tool, can be regarded as a machine, to be designed for a specific purpose. In this design the special tool is the cutting edge and the internal systems of transportation,whereby work is brought and

presented to the special tools, correspond to the feed motions. While, of course, it is unsafe to carry this analogy further than it can safely bear, yet it would seem that it would be possible to formulate certain general principles which can be recognised as underlying successful practice. It will be a disregard of certain of these principles which will make it impossible for one shop to compete with another and make money when a proper attention is paid to the cost of manufacture.

An interesting modern tendency, furthermore, which has a very distinct bearing on the cost of production, is the tendency to employ labour of moderate skill and even of moderate physical strength to operate special machines in large numbers, under the guidance of a limited number of supervisors of considerable skill. This refers to the growing practice in the New England section of the United States particularly, which favours the employment of women as operators upon machines of the class which men have hitherto considered their exclusive field. Such machines, carefully planned, and skillfully adjusted by the skilled foremen, can be operated, until readjustment is required, by a class of labour competent only to see that they are working properly and turning out the desired product. It will be apparent that progress along these lines means increased compensation for the really skilled operator upon the producer side, while the buyer or user of the product reaps the advantage of the cheaper cost of production. Assuming this principle to be likely to extend, the arrangement of the shop from the standpoint of superintendence assumes a position of great importance in the general scheming of the shop as a tool, while it is never absent in any arrangement or under any system of internal organisation.

It is a received principle that the higher-priced superintendent is more economical than the lower-priced man, provided his price is represented by real value in increased production. In this view, the greater the output of such a superintendent through the men under him, the less proportion of his expense is chargeable to each unit of output. It would appear, therefore, that such a construction of shop buildings was imperatively necessary as would permit such supervision and direction to be effective and immediate. This makes an arrangement of shop on two sides of a square, in the shape of a letter L in plan, or upon three sides in the shape of a letter E in plan, to be an undesirable arrangement. The part that is invisible to the superintendent when he is engaged in one wing, loses the stimulus of the master eye, and this difficulty increases as the linear dimension of the establishment increases.

Worse still is the arrangement of a department upon more than one story or floor of a building, if one man is to be charged with its oversight. If a difficulty arises which the drawings will not answer, or some responsibility is to be taken and the man who has to shoulder this burden is half a block distant, or is out of sight, up one or two pairs of stairs, human nature will wait till he comes around or down again, rather than take the trouble to hunt him up. Meanwhile, perhaps, also, the less gifted is seeking and getting advice from the better informed tool-hand at his side, and the younger lads are skylarking at the water-pail, and the economy of production is leaking out through the scuppers on the lee side, because the wage account goes on with the ticking of the clock.

It may be, furthermore, that the shop belongs to that group where a certain proportion of repair or jobbing work moves at the side of the regular standard product, and the services of the draughtsmen are required to match the new work with the old. Where such an arrangement exists as to force the drawing room to a location at a considerable stretch from the superintendent's office and his table for laying out work, there is an amount of time, paid for at draughtsmen's and superintendents' rates, which is consumed in profitless pedestrian achievements which would be dear at any price. Human nature in the shop,

again, will often take risks in a happy-go-lucky confidence that it will work out right somehow, which is fatal to the best work because no one cares to spend himself if he has a suspicion that it may not be worth while for him to do so.

The conclusion from the foregoing considerations is the preference for the one-story shop, arranged in a straight line, and including one department under one supervision. This arrangement permits of growth on the ends, lengthwise, should expansion be called for, short of the requirement of entire duplication. The source of power should obviously be an annex at the middle of one of the long sides, if the shop generates its own power from coal. This permits of easy approach of fuel supply and the removal of ashes and refuse. It diminishes insurance risk and lightens the weight of transmissive machinery if shafting and belting are used or preferred. The modern transmission of energy by electrical means over wires has diminished the importance of this central location of the power plant, and has permitted the giving of a proper weight to other considerations which previously have had to give place to the exactions of the lines of shafts. This arrangement passes into the ground plan, which resembles a letter H by doubling the first shop on the other side of the power house annex. This second shop, however, should be a second department, having its own supervising force.

It has been said that in the past shops have had to be designed to a great degree upon the lines laid down by the requirements of the lines of the shafting and belting. This limitation has often interfered most seriously with the second great principle of arrangement which was referred to in the opening paragraphs as the "feed motion" of the shop when regarded as a tool. The general principle in handling heavy work is the same as that in handling large numbers of persons. It may be briefly stated that the currents of work through the shop should never cross one another if possible; and under no circumstances should they ever meet when moving in opposite directions. This principle can be disregarded where all work is so light as to be handled by hand only. But when the masses of metal become great enough to require power appliances which must, of necessity, have definite paths, over fixed lines, the leakage loss of time when gangways are blocked at intersection points commences to mount up into considerable figures, because the loss is multiplied by the time of several persons. This principle should be regarded in the works as a whole and in the individual shop.

The worst condition is met where shipment of finished work by drays and otherwise from the erecting floor must take place through a door which is also the entrance for castings and forgings from outlying shops. The streams from the foundry, the forge, and from the outside sources of repair work should converge and enter the machine shop proper at one end. They should there be met by the first or principal tools, and probably those of largest capacity also, upon which the first finishing processes will be done. They should then move forward along the line of subsequent processes until, at the other end of the building, they reach the erecting floor where they will be assembled and the final fitting and adjustment done. Beyond this should be an area where the parts may accumulate after being taken down for proper slushing, boxing, crating, etc., and the door for the shipment of finished work should be beyond, again, or at the end of the building. If shipment is to be by rail, a whole paragraph might properly be devoted to considering the conditions of convenient trackage at this delivery end. It is, furthermore, a small matter apparently, but it has a distinct cash bearing, that the tools and workmen near the shipping door, when the latter has to be open during cold weather, are forced to a considerably diminished productivity by the inconvenience and discomfort to which they are subjected by the shipping process.

If, on the other hand, the currents of work are continually eddying back and

forth, it is impossible to prevent collisions where two pieces of work will meet upon the right of way, if there is an adequate provision for appliances for internal transport, or in the absence of such facilities one set of men and their work must wait in idleness until the other job has reached its destination.

This discussion opens a door to a reference to the best methods of internal transportation which constitute the mechanisms used to produce the feed motions of the tool. The overhead travelling crane in a central bay, driven by electrical means, seems to be the present accepted standard for internal transport. Its flexibility, its speed, its capacity, and its availability are all strong arguments for this method and system. The track, however, for the crane compels a straight-line ground plan for the area which it covers, and it must necessarily be a single-track affair, because no satisfactory method has been found as yet to have two travelling cranes pass each other when both are loaded.

Considerable advantage is secured by having, in addition to the crane, a system of floor tracks, with turn-tables, so that a double system, or two systems of transportation, can both be in progress at once. Ball-bearing buggies run very lightly upon tracks of this sort, and will again prevent, in part, that tendency of human nature in the shop to wait many minutes of costly time for the overhead crane rather than to expend personal muscular energy in the transportation of an article weighing over 100 pounds. The suspended single trolley rail, with switches, is also a most convenient subordinate appliance to reach points where neither the floor track nor the overhead crane can quite meet the requirements. The area of the shop devoted to erection and shipping in busy times and in prosperous seasons may properly utilise the time of one travelling crane.

Another principle having a close relation to economic production is less related to the arrangement of the shop upon the drawing board than to its design as respects the selection of its equipment. The principle is that of so choosing the tools and the machinery which serves them that they shall be always earning the interest upon their cost. The interest account of an idle tool charges up continually to the expense account of the works without a counterbalancing credit upon the job or product for which money is received. Some works refine this process of charging interest by a tool charge item, which varies with the size of the tool with respect to capacity for large work, which, again, usually varies with its cost. This is an argument against the use of composite tools of which only one part, as a rule, is earning interest at a time, and for which the losses of time in changing from one use to another have no offset in productive return.

It is here, furthermore, that the expert foreman can earn his increased value by putting a tool intended for one purpose to relieve a congestion at other parts of his shop. He thus prevents delay, increases the output and makes more tools self-supporting. It is obviously impossible to lay down general principles which shall cover any range of specific work. The principle, however, is believed to be a sound one.

No reference has been made to those features of arrangement which have to do with economical heating from a central station, and incidental mention only has been made of the question of an arrangement which shall affect insurance problems favourably. The necessity and location of yard areas, stock house, paint and varnish shop and other auxiliary departments leaves a field open for discussion for which no present space is permitted. The writer's object will have been secured if, by a brief treatment, which emphasises the commercial significance of what would appear to be purely technical questions, he shall stimulate thought along these lines which shall be helpful and suggestive.

ENGINEERING IN THE UNITED STATES NAVY

ITS PERSONNEL AND MATÉRIEL

By Rear-Admiral George W. Melville, Engineer-in-Chief U. S. N.

ON the occasion of the last annual meeting of the American Society of Mechanical Engineers, Rear-Admiral Melville chose for his presidential address the subject of naval engineering, with special reference to what had been accomplished in this branch in the United States. With the decided change that was effected last year in the personnel of engineering in the American Navy, it was particularly appropriate that one of its engineers of the old school should, at the close of this chapter in its history, give a review of some of the more important facts with respect to both personnel and matériel, and Admiral Melville's remarks have, therefore, been here given almost in full, specially revised for this purpose.—THE EDITOR.

Every American is naturally proud of the fact that the first successful steam vessel was the work of an American engineer; but it is not so generally known that the first steam war vessel of any navy was designed by the same American, Robert Fulton, and was built at the city of New York in 1814. Had the war with Great Britain lasted a little longer there can be no doubt that the *Demologos* would have created a revolution in naval architecture; but the close of the war before she was completed rendered her active service unnecessary, and she was finally destroyed by an explosion of her magazine in 1829. The advent of the *Demologos* did not create an engineer corps, nor bring any engineers into the navy, so that the real beginning of naval engineering was when the steamer *Fulton* was built, and in 1836 Mr. Charles H. Haswell, the Nestor of engineering in the United States, became the first chief engineer in the United States Navy. The *Fulton*, shown on page 478, was a small vessel of only 1200 tons displacement, or about what would now be considered a small gunboat; but she was the beginning of what has brought about as great a change in navies as the invention of gunpowder did in warfare.

It is really wonderful to think that the man who was the first chief engineer of this first steam war vessel of the American Navy is still alive, in full possession of his faculties, and in the active practice of his profession to-day. One of his contemporaries some years since said that the engineer corps might consider itself very fortunate in having had for its founder such a man as Mr. Haswell, an educated gentleman and a thoroughly competent engineer. From the very first his every effort was devoted to increasing the efficiency both of the machinery and of the officers who were to care for it, and it is not going too far to say that he has left a lasting impression by his labours, the organisation and scheme of examinations having long remained as he made them. It may not be amiss here to refer more particularly interested readers to the admirable portrait of Mr. Haswell which appeared in this magazine last month.

THE UNITED STATES WAR STEAMER "DEMOLOGOS." BUILT IN 1814

It is a little hard for the young engineers of to-day, whose training, while it may seem to them beset with difficulties in the way of intricate formulæ and abstruse calculations, is, nevertheless, complete, and makes them masters of an immense amount of accumulated information, to realise the difficulties under which the older engineers, even of the writer's generation, and much more so of Mr. Haswell's, laboured. Mr. Haswell himself was one of the first to provide a reliable book of reference for the young engineer, where the results of experience were systematically arranged; but for Mr. Haswell himself there was nothing of this sort, and he had to create the precedents. When we look at the matter in this light, we are filled with admiration for Mr. Haswell and the men of his generation at their excellent solution of the problems which confronted them.

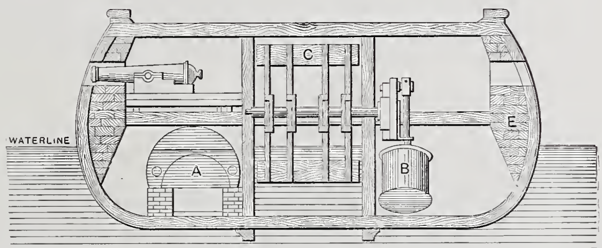
Without going into a detailed sketch of the work done by Mr. Haswell, it may be well to recall to mind a famous old ship, the machinery for which was designed by Mr. Haswell, who, indeed, made all the drawings for it himself. This vessel was the *Powhatan*, shown on page 481, which for many years was one of the finest of the old American ships and rendered most efficient service. She was built in 1847, and remained in active service for forty years, a monument to those who had designed and built her.

In those early days the average deck officer of the navy did not look upon the steam engine as a desirable addition to a ship, but simply as a necessary adjunct that had to be endured. There were, of course, notable exceptions, and Captain Matthew C. Perry, the first commander of the *Fulton*, was a liberal-minded man to whom engineers owe a great deal. Yet, even he hardly rose to the point of considering that engineers were a vital part of the ship's complement, and as such should be made to feel that they were as much officers as any others, and their men were just as truly sailors. Neither Mr. Haswell, nor any of his assistants, were regarded, when first appointed, as permanently in the navy, and the assistant

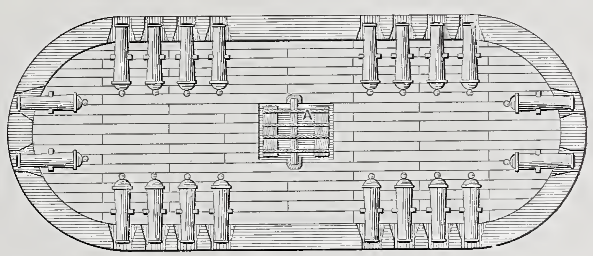
engineers were removable summarily by the commandant of the station. Some years ago Passed Assistant Engineer Bennett, writing for one of the reviews, in speaking of this circumstance, expressed surprise that the deck officers should not have realised the mighty force which steam brought to them and have embraced every opportunity to take advantage of it. It seemed, on the contrary, to belong to a different world from that in which they had been trained, and instead of endeavouring to become expert engineers, they regarded the machinery and all connected with it as a disagreeable necessity and left its development to the separate corps of engineers.

Some years before the American Civil War another great marine engineer began to attract attention, —Benjamin F. Isherwood. He entered the navy in 1844, so that he is really a contemporary of Mr. Haswell. It is, perhaps, not exaggerating to say that he is the most brilliant marine engineer whom America has seen, and his work has made his name known among marine engineers in all parts of the world. His fame will probably rest mainly on his record as an experimentalist, in which field there are few who have ever exceeded him, either in the amount or the excellence of the work done.

The most notable of his experiments was the series which gave the complete demonstration of the relation between cylinder condensation and the rate of expansion. Until these experiments, most engineers believed that the law of Mariotte, that the product of pressure and volume is constant, was strictly applicable to steam as well as to permanent gases, and that a very large ratio of expansion with low pressures of steam would be profitable. Isherwood's experiments on the U. S. S. S. *Michigan* demonstrated conclusively that under the conditions there obtaining, of a slow-moving engine and a low steam pressure, a ratio of expansion was soon reached beyond which any increase would cause an absolute diminution of economy, instead of an increase thereof, as would have been predicted from a strict adherence to Mariotte's law. Every young engineer knows this thoroughly to-day, and is cautioned about it in his text-books; but so far from its being readily accepted when Isherwood's experiments had demonstrated the true facts, many will remember that he was assailed in the public prints as being guilty either of hopeless ignorance or willful waste of the government money.

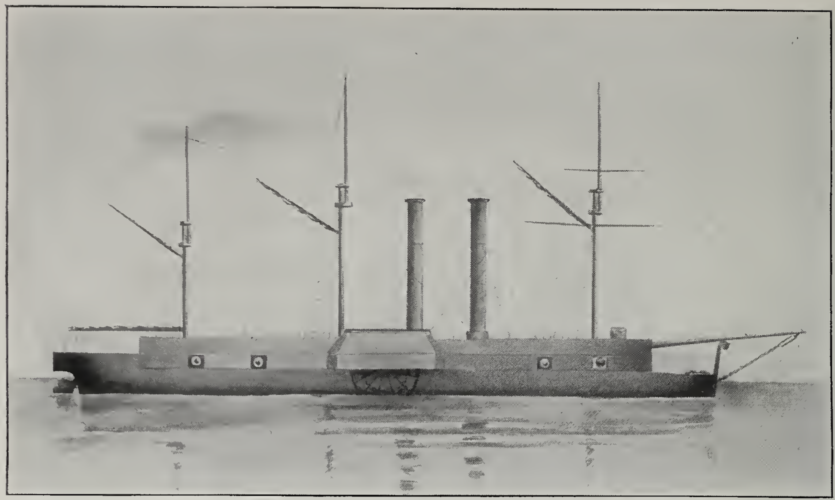


CROSS-SECTION OF THE "DEMOLOGOS." *A*, BOILER; *B*, ENGINE; *C*, WATER-WHEEL; *E*, WOODEN WALLS, 5 FEET THICK



PLAN OF GUN DECK

Mr. Isherwood was not only a splendid experimentalist, but a designer of the first rank, and an executive engineer who has not been surpassed. He was Engineer-in-Chief of the United States Navy during the whole of the War of the Rebellion, and during that time was responsible for a large number of designs. Here, again, he was criticised from the academic point of view, and yet the very faults for which he is criticised appear, on proper analysis, only



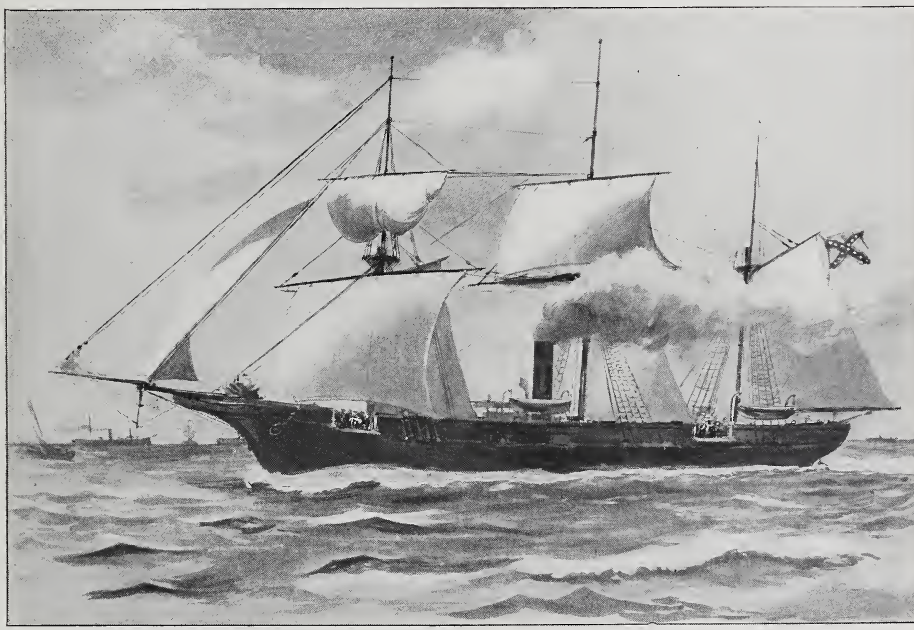
THE U. S. STEAMER "FULTON," 1837

the more praiseworthy as excellent details of sound designing. He was accused of building engines which were inordinately heavy, which accusation he has never denied. To the mere office engineer this was true, but he realised what they did not, that these engines had to go into the hands of men who were largely untrained and unfamiliar with machinery. The ordinary formulæ for design assume reasonably decent handling, and do not provide for the stresses due to ignorance and carelessness. Isherwood knew that the point of first importance was to build engines which would not break down, and, in fact, could not be injured by ignorant and careless handling. The result of this policy was engines very much heavier than would ordinarily be built; but they did not break down, and they carried the ships to victory. To my mind, this was the highest proof of his talent as a sound designer. He had the courage to invite criticism from the book engineer in order that he might insure success for the country.

The story of the *Alabama*, and how she and her sister commerce destroyers drove the American merchant marine off the ocean, is well known. The Navy Department felt it important to get a class of vessels that would be faster than the *Alabama*, or any vessel likely to be built, so that they could sweep the seas of all these commerce destroyers. A number of designers were concerned in projecting both hulls and engines to accomplish this result, but although the great Ericsson was one of his rivals, Isherwood's ships were the only ones which really accomplished what was intended. The *Wampanoag* was the first of Isherwood's ships to be tried, and she was a magnificent success in every way,—really in many ways the greatest success as a steam war vessel that the world has ever known, because she distanced everything that had preceded her so much more than has ever been accomplished before or since. The *Wampanoag* was given a trial lasting 37½ consecutive hours between Sandy Hook and Cape Hatteras, and for the whole run averaged nearly 17 knots per hour. During several 6-hour periods her speed was over 17 knots, and for several single hours she made over 17½. It should be noted also that this was not a smooth water run, as the trial was ended prematurely owing to a gale, and for some time previous the weather was heavy. The speed made by the *Wampanoag* was at least 4 knots more than that of any other ship,—either mercantile or naval,—of her period, and, in fact, it remained the record speed for many years. Even the first fast cruis-

ers of modern navies, like the *Esmeralda* and *Naniwa*, while nominally credited with a higher speed, made it only over the measured mile, or for a short spurt, while the *Wampanoag's* record was, as stated, for more than 37 hours. Another of the Isherwood ships, the *Ammonoosuc*, was given only a short trial, but showed qualities equal to those of the *Wampanoag*. The best of the rival ships made a speed of about 15 knots for less than an hour, and the other vessels fell below the *Wampanoag* even more than this.

his ideas. It would be supposed that Isherwood's brilliant achievements would have brought him only gratitude and thanks; but, on the contrary, his vigorous methods had aroused a great many enemies, so that at the end of his second term as Chief of the Bureau of Steam Engineering there was sufficient influence to prevent his reappointment to the office which he had so well filled, and he was banished to the Mare Island Navy Yard; but this only gave him an opportunity for some of his best experimental work, and the famous propeller

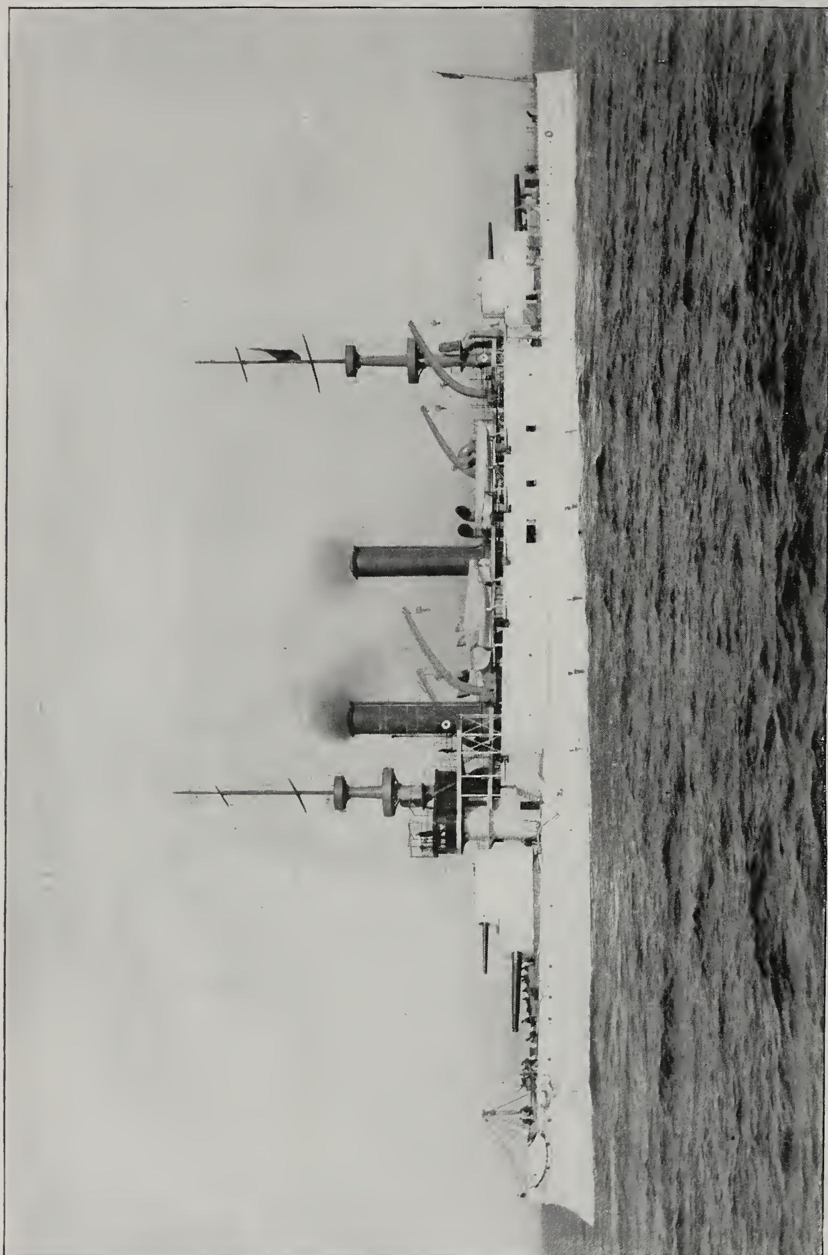


THE AMERICAN CONFEDERATE CRUISER "ALABAMA," DESTROYED OFF CHERBOURG, FRANCE, ON JUNE 19, 1864, BY THE U. S. CRUISER "KEARSARGE"

It is not, perhaps, generally known that in calling the *Wampanoag* an "Isherwood" ship the designation is more inclusive than might be supposed at first glance, for Mr. Isherwood was responsible for those features of the hull design which affect speed. The design of the hull, as a whole, was worked out by Naval Constructor Delano, an accomplished naval architect; but he simply took the form of hull as designed by Mr. Isherwood and worked out the structural details necessary to carry out

experiments, which are still a mine of valuable information for designers, were conducted there with the assistance of Mr. William R. Eckart, a former engineer of the navy.

After these experiments, and until his retirement, Mr. Isherwood conducted many others which have given valuable information to engineers, and it may be well, in passing, to remark that his reports of experiments are models to which all young engineers can refer with great profit to themselves.



THE BATTLESHIP "KEARSARGE." THE LATEST ADDITION TO THE UNITED STATES NAVY. BUILT BY THE NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY, NEWPORT NEWS, VA.

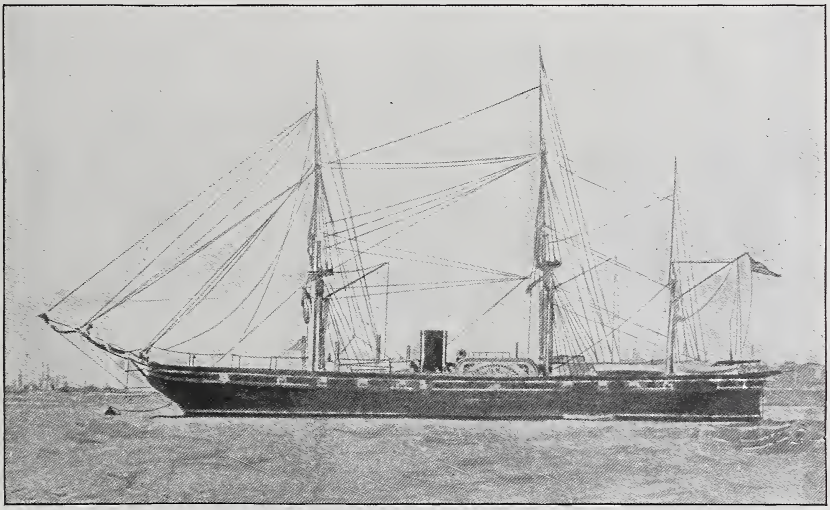
The thoroughness with which the apparatus under experiment is described and its dimensions are given, the elegance and lucidity of the language, and the admirable arrangement, are all models of what such a report should be, just as Macaulay's style is so justly commended to all young writers.

From a remark which has just been made as to the qualifications of many of the engineers who came into the navy during the War of the Rebellion, it might, perhaps, be inferred that there were few men of real ability; but this would be unwarranted, and would be an entire mistake. The total number of engineers was so large that it was utterly impossible to have even a majority of them skilled men; but a number of talented young engineers came into the service, and the profession generally has learned to recognise their ability from the fact that in the years since the close of that war a large proportion of the leaders in mechanical engineering in the United States are men who were naval engineers during the war.

During all the period which we have thus far considered, the engineers for the navy had obtained their education outside of naval influence; but in 1866 a class of young men was ordered to the Naval Academy to be trained as engineers in a naval atmosphere. A number of these gentlemen are still in the service, and were chief engineers of the large vessels during the recent war with Spain. In 1871 engineer cadets were appointed for the Naval Academy, the course being for two years only, until in 1874 a class was appointed whose course was to be for four years.

These young men were appointed by competitive examination open to the whole country, and as the course became better known the numbers who came to compete increased, and their attainments became so high that an unusually able class of young men was obtained as cadet engineers. Unfortunately for the service, Congress was seized with one of its periodical fits of retrenchment, and as no patronage was affected by abolishing the cadet engineer system, the separate course for engineers was wiped out in 1882, and for a time engineering education dropped out of the curriculum at the Naval Academy.

It is probably safe to say that the young men graduated from the Naval Academy under the cadet engineering system presented a higher average abil-



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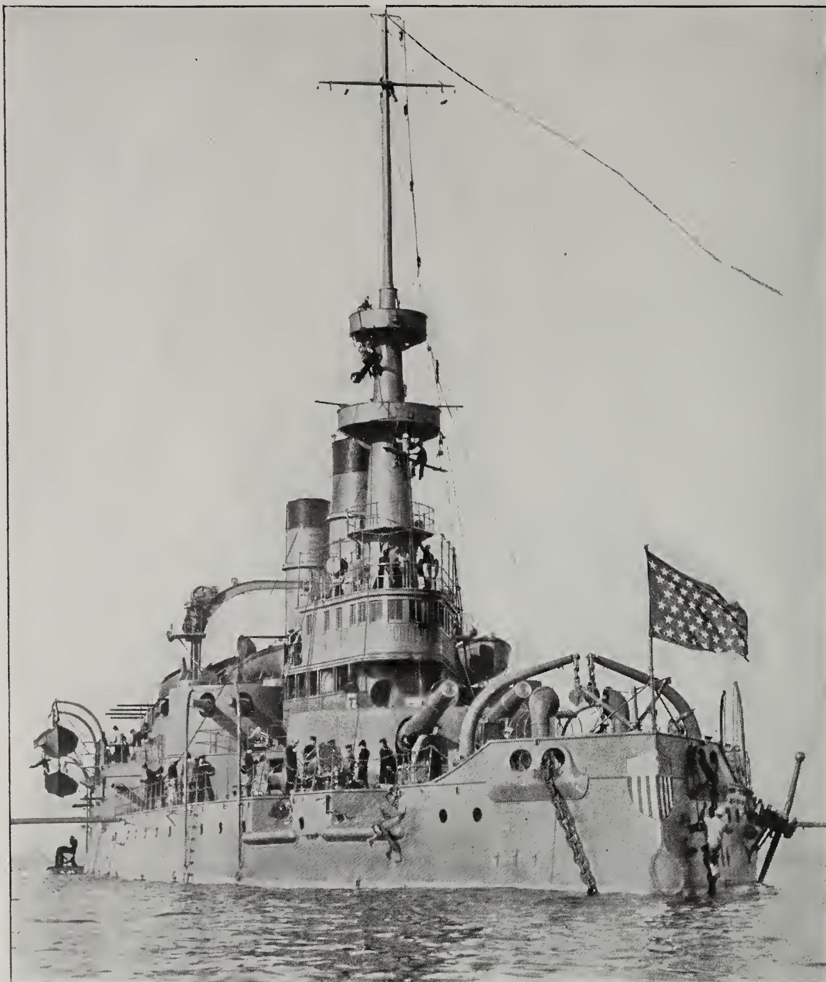
THE "POWHATAN," 1850



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THE BATTLESHIP "OREGON"

ity than any equal number of young men from any of the great technical schools; indeed, so great was their ability that the service was unable to retain them, but the country profited from the training they received by their work in civil life. A number are filling positions as professors of mechanical engineering in leading colleges; a number are consulting engineers of the highest rank, and several are engaged in the management of large manufacturing enterprises.

Curiously enough, just about the time when Congress was undoing the splendid engineering work at the Naval Academy, the United States Navy Department itself was formulating plans for vessels which should be designed along lines so different from those which had preceded that the familiar epithet applied to them,—the "new navy,"—is entirely appropriate. The labours of the first advisory board made available a mass of information, as a result of which Congress in 1883 authorised the building of the four cruisers, which were the beginning of the new navy. These vsesels, I may say in passing, although possessing few features of novelty, as far as marine engineering in general is concerned, were, nevertheless, a marked change from the old wooden ships which

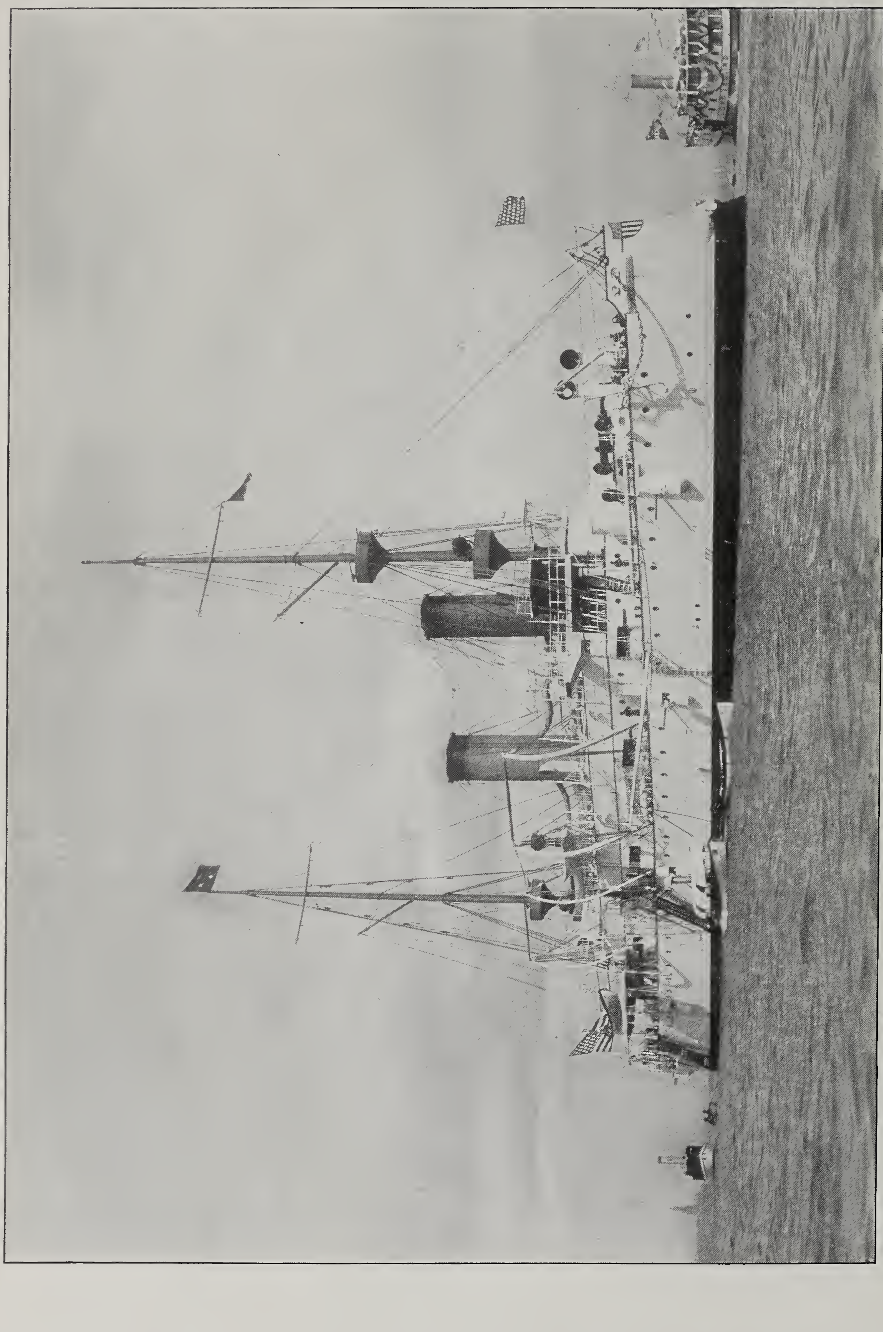
had preceded them, and they rendered very valuable service, and are still, with modernised machinery, very satisfactory and useful vessels.

In 1885, when Mr. Whitney became Secretary of the Navy, a period of great activity and progress was inaugurated in the Navy Department, taking what had been done by Secretary Chandler, who started the new navy, and carrying on the work along the lines of logical development. Mr. Whitney's determination was to have ships which should be fully the equals of those in any country, and it was through him that the writer was called to the position of Engineer-in-Chief of the navy in 1887.

I believe it is generally admitted that the machinery of the United States Navy has been in all respects fully abreast of the latest developments, and in many respects America has taken the lead. One of the first things done in the United States was to establish the use of water-tube boilers and light compound engines for steam launches. Private builders had used water-tube boilers, but the results, owing to the type of boiler employed, were not altogether fortunate. We found a boiler which has proved entirely satisfactory, and also developed light machinery which was also sufficiently substantial to stand the comparatively rough handling with which the machinery of small boats must inevitably meet. The United States Navy is to-day the only one which uses water-tube boilers exclusively in its small boats. At the beginning, the effort was made to save as much water as possible, and small blowers, run at a high speed, were used for draught, but the inevitable hum caused so many objections to be entered by officers of high rank that we were driven to the use of the steam jet. It was, of course, important that the most economical form of jet should be used, but when we came to determine this question we found that there were absolutely no reliable data in existence. As a result, we carried out a valuable series of experiments at the New York Navy Yard, and found an exceedingly simple form of jet, which was also very economical, giving us a fairly high rate of combustion for a comparatively small expenditure of steam.

It was evident to us that with the prevailing tendency toward continual increase of speed and power, with the accompanying increase of steam pressure, the shell boiler would at some near date have to be superseded by the much lighter water-tube boiler, and we, therefore, invited a competition among the various manufacturers of water-tube boilers, with a view to determining the one which, all things considered, would be best adapted to naval uses. As a result, we installed about 5000 horsepower of Ward boilers in the coast defence vessel *Monterey*, this being at the time, and for several years, the largest installation of water-tube boilers in any naval vessel. I am glad to say that these boilers have always given satisfaction and are still in use. At this same time water-tube boilers of a different type were installed on one of our torpedo-boats, and we have never used any other than water-tube boilers on any of the numerous torpedo vessels which have been built since.

It would have been an easy matter, and it would have brought temporary praise to the engineer-in-chief, if, after the successful trial of the *Monterey*, we had at once launched out into the use of water-tube boilers for all the vessels; but it was felt that there had not been sufficient experience in their use to warrant making such an experiment in the first sea-going armourclads, and consequently, for a number of years, and even after other navies had begun to use water-tube boilers extensively, we continued to use the shell boilers in our large vessels. Two years ago, when I felt that there had been sufficient experience to warrant us in the final adoption of water-tube boilers, I recommended in my annual report to the Secretary of the Navy that we should definitely adopt water-tube boilers for all classes of vessels. For reasons altogether apart from the machinery, we were not at first successful in securing water-tube boilers in the department's own designs, in spite of my urgent re-



THE UNITED STATES CRUISER "OLYMPIA." ADMIRAL DEWEY'S FLAGSHIP IN THE BATTLE OF MANILA, MAY 1, 1898

commendation, but the firms which tendered on the government's designs also offered to guarantee higher speeds if they were allowed to use water-tube boilers and more powerful machinery in hulls of their own design. This I had advocated very strongly, and both the technical and daily press of the country had supported this position very heartily, believing that it would be a woful mistake for the United States to build 16-knot battleships when the rest of the world were building vessels to make 18 knots, and when by the use of water-tube boilers we could so readily do it. I am glad to say that the department accepted the builders' offer, thus definitely adopting water-tube boilers and securing the 18-knot battleships for which I had worked so hard. At the present time all the new American designs include water-tube boilers exclusively.

One of the notable improvements in design which we introduced for large vessels was the use of triple instead of twin screws. We were not the originators of this method, as small vessels in both France and Italy had demonstrated its success, and both France and Germany were building vessels of about 12,000 horse-power with this system of propulsion. When it came to the design of the *Columbia*, the first of the American commerce destroyers, with 21,000 horse-power, I was satisfied, after careful study of the problem, that we would need triple screws to attain success. At the beginning I did not anticipate an economy in propulsion, and the adoption of triple screws was for structural reasons; but when the *Columbia's* trial occurred we found that there was a material increase in the propulsive efficiency. When the *Minneapolis* was tried shortly afterward with the same system of machinery, this fact of greater economy was again established, so that we now feel that triple screws are justified not only for numerous other reasons, but on the ground of economy. This arrangement of propellers has become very popular in a number of other navies which have followed it out on a considerable scale, and have built all their large vessels with triple screws. It is probable that we shall do the same thing in our larger ships of the new programme.

During our late war with Spain we developed and utilised two engineering schemes which had never previously been tried in actual service,—a repair ship and a distilling ship. The former is one phase of the modern method of treating large work by taking the tool to the work instead of bringing the work to the tool. The *Vulcan* was the equal of anything except a very large repair yard, and after the battle of Santiago she was almost invaluable in the much needed general overhaul of all the ships. Besides an admirable outfit of machine tools and engineering stores, the *Vulcan* was specially notable for using the first cupola ever installed on board ship. The distilling ship was fitted with a four-unit, triple-effect distilling apparatus capable of furnishing 50,000 gallons of fresh water per diem after use for some time with an economy of over twenty pounds of water per pound of coal burned under the boilers. With clean coils the *Iris* actually furnished over 100,000 gallons per diem. The bunker capacity is 3000 tons of coal, thus giving a potential capacity of distilled water of 60,000 tons, or as much as twelve of the largest tank steamers. The advantages of a distilling ship over a "tanker" are very numerous and obvious.

The war with Spain was too short to give a chance for great experience in any line, but the work of the *Oregon* stands out as a brilliant illustration of the fact that the modern battleship is not only the creature of the engineer, but is absolutely dependent upon him for success. Every one now knows the story of Milligan's work as the chief engineer of the *Oregon;* of his ceaseless vigilance to keep everything in order and prevent any deterioration; of how he saved the good coal for the day of battle which finally came (though he was told it never could come); and, above all, how he persuaded Clark, the commanding officer, to have all the boilers ready all the time, although others had steam on

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THE UNITED STATES CRUISER "CHICAGO" IN REMODELLED FORM

only half the boilers, and, where it could be done, half the engine power was laid off. I am firmly convinced that the brilliancy of the victory at Santiago is largely due to Milligan's skill and foresight, and, as I said, this case is direct proof that however admirable as a great fighting machine, the battleship is useless except in the hands of trained engineers.

During the last fifteen years naval engineering has shared in the general progress of all marine engineering, and has led in many respects. Wrought iron, which was formerly the mainstay of the designer, has practically disappeared, to be succeeded by mild steel, which is not only stronger, but much more reliable, and the manufacture and inspection of which has been brought almost to perfection. There is little doubt that the great improvements which have been made in both engines and boilers would have been impossible but for the greatly improved material. One of the greatest advances has been in the reduction of weight of machinery, and this has been due both to improved material and to radical changes in design. In the engine there has been a better disposition of the material; and the use of hollow instead of solid shafting and other large pieces of forged material, the use of steel castings, etc., has been instrumental in enabling the use of higher pressures, and particularly of higher rotative speeds. These rotative speeds have become possible since we have learned to design the propellers on rational principles. In the old days the rule was to make a propeller as large as possible, consistent with immersion, and this, on account of the empirical rules for the ratio of pitch to diameter, necessarily kept down engine speeds. Now we know that within reasonable limits we can design a propeller to suit almost any engine speed; consequently, we are left free to adopt as high a rotative speed as is desirable and consistent with safety, assured that we can afterward design an economical propeller to fit it.

In the boilers, the reduction of weight has been due, apart from the more recent adoption of the water-tube type, to improved material, and especially to forced draught. This is an American invention almost contemporaneous with

Fulton's early steamers; but it had almost disappeared, and after a brief revival under Isherwood during the American Civil War, had again died out until it was taken up in some of the foreign navies. At the present time no naval machinery is ever designed without the use of forced draught.

Pressures have been gradually rising, and even with shell boilers as high a pressure as 200 pounds has been employed; but with the present plans of using 250 pounds at the engine, with either triple or quadruple expansion, and some 25 or 50 pounds more at the boilers, nothing but the water-tube boiler would do.

At the present time it seems as though practically the highest development possible had been reached with existing types of machinery for naval purposes, leaving the designer room only for greater perfection in details. We do not, of course, believe that finality has actually been reached, and it is possible that some radical change may take place which will give us a new type of machinery. Some of the more enthusiastic members of the profession think that the steam turbine is to be the successor of the present steam engine, and assuredly the performance of Parsons' *Turbinia* is sufficiently remarkable to justify the most careful study and further experiment.

It may not be amiss here to refer briefly to that much-discussed subject, the personnel of naval engineering. For many years there had been an unfortunate controversy in the United States Navy, known as the "line and staff fight," resulting from the fact that the line officers, as the older organisation, were unwilling that the staff, and especially the engineers, should have all the rights to which the latter believed themselves, as naval officers, entitled. The great grievance of the engineers was that they held what was called "relative rank" and were denied the command of their men and a military title, so that there was always room for the statement, which unfortunately was made at times, that they were not really officers and had only a *quasi* rank.

All men who have passed middle age have probably realised personally the difficulty of bringing about any radical change in existing conditions of long standing, and I really believe that the trouble in the navy was largely a matter of inertia. An enormous amount of valuable effort was wasted on both sides; the one to secure the coveted rights, the other to prevent this result; but matters had been shaping themselves for a considerable time so as to make a new state of affairs inevitable. The change in the means of offence on board ship had brought the line officer to the point of realising that he must, of necessity, be a good deal of an engineer, and such work as the manufacture of guns, which is, of course, purely mechanical engineering, showed this very strongly. On the other hand, the work of the naval engineer on board ship, which had originally been to direct a very few men with small machinery, has been gradually changing, until, on some of our large ships, the chief engineer commanded in fact, although not in name, about half the crew; consequently, his duties had become very largely executive and military, and thus of the same nature as the duties of the line officer. As a result of this state of affairs, many of the more liberal minds on both sides believed that the solution of the vexed question in the navy was the consolidation of the line and engineer corps, and making the new line officer an engineer as well as a sea warrior, or, as it has been aptly put, a "Fighting Engineer."

A board of naval officers finally formulated a scheme for carrying out this idea of amalgamation, which was actually proposed in the board by a line officer. When it was submitted to Congress, two members of the House Naval Committee took up the measure very actively, and with the assistance of other members of the committee, pushed it forward to complete success, until the Personnel Bill became a law on March 3, 1899.

Under the provisions of this law the officers of the engineer corps were transferred to the line and given new commissions as line officers with actual rank,

thus effectually disposing of the phantom of relative rank. I wish particularly to emphasise the fact that the basis of tne law, and the consideration that led to its adoption, was the demonstrated fact that to have a successful navy every line officer must be a thorough engineer.

A natural inquiry will be, how successful is this measure in actual practice? To this the answer is that any such change must, of necessity, require time, and it is too early yet to speak of results. I wish, however, to put on record my opinion that if the administrative details necessary to carry the law into effect are worked out with an honest desire to give due effect to its plain intent, and with a desire to make it a success, the results will be all that can be wished.

It may occur to some who have only looked into the matter hastily that this scheme of amalgamation is contrary to the spirit of the age, with its tendency toward specialisation; but, as an actual fact, the reverse is true. The misapprehension comes from a failure to thoroughly consider the case. When it is proposed to make every naval officer an engineer, we mean an engineer specially fitted for the work to be done in the navy, just as the other training of the line officer is for the duties which come specially to him; in other words, this new line officer,—the "fighting engineer,"—is to be a specialist in the very best sense of the term; that is, a man who has been specially and thoroughly trained for the work he has to do.

The amalgamation is analogous to that which occurred in the British Navy just after Cromwell's time, and the analogy is not a fanciful nor forced one, but is strictly accurate. Up to the time of that change naval vessels were manned by soldiers who did the actual hand-to-hand fighting, but were entirely ignorant of seamanship, and another set of men who managed the propulsive power of the vessel, which was then the wind acting on the sails, and who directed the movements of the vessel. These men had no military rank, and were designated simply by professional titles, being known as "the sailing master and his mates." The amalgamation which then occurred was of the soldier and the sailor, and out of this amalgamation was evolved the man-of-warsman and the naval officer. With the advent of mastless ships, we had reached an analogous condition where one set of people fought the guns and another set managed the propulsive power, this time steam acting through machinery. The new amalgamation has made a new naval officer, "the fighting engineer," to be followed in time by the successor to the old man-of-warsman, who will be the "fighting mechanic." The basis of the new amalgamation is the fact that in this industrial age engineering and mechanical skill are the source of efficiency in any navy.

THE BRITISH ENGINEERS' STRIKE OF 1897-98

ITS LESSONS AND RESULTS

By Louis Cassier

AFTER the lapse of over two years of active and peaceful working, following upon the now historic period of storm and stress in the engineering trades of Great Britain, in the autumn and winter of 1897, the time is opportune to review the whole circumstances of that great strike, and to set forth the results of that memorable struggle. This can be better done now than was practicable at an earlier date whilst some of the heat of the conflict remained. It is more possible now to take a calm and impartial view of the events, and with unbiased mind to form judgment on the sequel. It was, without doubt, one of the most momentous struggles in the history of industry. No other can be recalled which has had such far-reaching results, and none conducted with so much heat that left so little bitterness behind it. The most striking and beneficent result of the conflict has been the peace and good-will which has prevailed since it ended.

On April 1, 1897, there met in the Westminster Palace Hotel, London, representatives of the Employers' Federation of Engineering Associations and of the Amalgamated Society of Engineers to discuss certain differences which had arisen at Pallion (Sunderland), Barrow, Elswick, and elsewhere. These differences related to the manning and rating of machines, the wages and allowances to men on trial trips, the allowances for "lodging money," and to arbitrary stoppage and restriction of overtime. Save with regard to the operating of machines, an agreement was at this conference effected on all the points at issue; but as the employers resolutely declined to accede to the claims of the Amalgamated Society of Engineers to have all machine tools reserved for their members, what came to be known as the "Machine Question" was for the moment suspended by the representatives of the men. When the April conference separated without having settled this question, the society officials felt that it would be bad policy to challenge a fight over a matter on which they could not count on popular sympathy and general trade union support. Therefore, they challenged the employers over the eight-hours question in the London district, though well aware that all the Federated Employers were bound to concerted action, and that such a movement could not be confined to the metropolis. The strike to enforce the eight-hours' day, or forty-eight hours' week, in London was, indeed, equivalent to a declaration of war all over the country between the Amalgamated Society of Engineers (for the other members of the Trade Unions Alliance were of minor importance in the struggle) and the Employers' Federation,—a war to determine who should have dominion in the engine-shop,—master or man. This became the real point at issue.

For seven months that war was carried on with all the energy and resources of the two greatest industrial organisations ever known,—the largest and wealthiest trade union in the world, and the strongest defensive combination of employers ever attempted. To the impartial onlooker who watched the steady

enlargement of the circle of Federated Employers, and the steady decline in the war-chest of the trade unions, the issue was never doubtful. It was only a question of time, and beyond doubt that time was prolonged by two things, —the large pecuniary assistance afforded from the outside to the contesting unions, and the intervention of the Board of Trade.

One of the most remarkable things about this great industrial war was that, while it was carried on for months with unremitting "sound and fury," and amid a perfect din of journalistic howling, it ended as quietly as a golf-match. No shout of victory and no cry of despair were heard when peace was at length signed and the engine-shops were re-opened in February, 1898. Those who have watched other industrial struggles marvelled at this sober ending to an excited campaign. But it is easily explained. The victors were too weary and sorely bruised for jubilation, and the vanquished had long foreseen and recognised the inevitable defeat. The two outstanding features of the struggle were the grim adhesion of the men, amid much privation, to their unions, and the splendid loyalty of the Federated Employers to one another and to their joint cause. For the maintenance of the union ranks one may find an explanation in the dangers and discomforts which attend backsliding in such circumstances, and also in the fact that men who have for years paid into what should be a provident fund are naturally loath to forfeit all the benefits for which they have been providing. The firm and unflinching loyalty of the employers to the Federation, and the rapidity with which that Federation went on increasing, until, at the end of the war, it included four or five times as many members as at the beginning, must be accepted as proof positive of the vital quality of the issues at stake. A more complete, whole-hearted and well-directed organisation was never effected, and it marked the beginning of a new era in the relations between capital and labour in the United Kingdom. Without doubt the most outstanding feature of the crisis was the complete success of the policy of the Federation of Employers' Associations,—rational combination in the interests of justice, liberty and the rights of property. What the Engineering Federation demonstrated, the federated coal-owners of South Wales later learned to appreciate, viz., the value of co-operative effort in a common cause,—the power for good of interests focussed in one comprehensive design for the benefit of each and all. The settlement which the Federated Engineer Employers attained by combined effort was one that they could not have secured as individuals, or even as local associations of employers. What they attained was also for the national as well as the individual benefit, for they placed the engineering industry in such a position that it could again be pursued in fearless competition with foreign producers, and with quickened enterprise. The employers were not waging war against trade unionism, but in the defence of their own rights and property from the aggressions of trade unionism. And having succeeded in their design, they were more inclined to bury the hatchet than to execute a war-dance. Never was there a better example of the principle,—"in union is strength." And the necessity for industrial employers preserving a firm, united front is as great as ever. Trade unionism as an aggressive force is not vanquished, though defeated. Employers everywhere are realising how insidiously socialism has wormed its way into trade unionism, until in many industries absolute freedom among workmen is unknown, and absolute individuality is regarded as something like iniquity.

By way of illustrating how absolutely necessary it has been for some large body of employers in some leading industry to take definite action for the vindication of the freedom of labour, the following is taken from a report of the Amalgamated Society of Steel and Iron Workers of Great Britain. It refers to the famous "Allan V. Flood" case:—

"Their Lordships have made it quite

clear that a trade unionist can at any time decline to work with non-unionists. In our trade we have still some of these useless humbugs, who allow the Society men to do all the fighting and then step in and take a share of what has been gained. No doubt they are not so numerous as they were, but their number must be still further diminished. Our executive has given power to any branch to stop work if they choose, as a protest against the employment of these men. This question must be kept to the front,—everything else is of secondary importance. Union from end to end of every shop must be the watchword."

Observe here how the leaders and officials of this important trade union characterise all non-union workers as "useless humbugs," to be somehow, or anyhow, obliterated. Yet these trade unionists might surely perceive that if they have the legal right to refuse to work along with non-unionists, employers have an equal right to refuse to employ unionists. Not all employers care to exercise this right,—though some, with effect, do,—but most union leaders have, apparently, not the sense to see that they are defeating their own aims in pursuing practices which must eventually end in compelling all employers to exercise this right. It is a delusion to suppose that the trade unions in all the skilled trades include all the best workmen; indeed, in most industries the very best workmen are not trade unionists, for the very good reason that they can do better for themselves on their own individual merits. These men of extra skill and manly independence are among the "useless humbugs" whom the officials of the Amalgamated Society of Steel and Iron Workers would like to suppress. That policy is not peculiar to this union. It is a part of the general policy of the labour leaders, who aim at the absolute control of the machinery of production, and who challenge the right of any employer of labour to manage his own establishment in his own way,—just as the officials of the Plasterers' Union brought about a general strike in Great Britain rather than allow the free play of honest industry.

Another thing which the Federation of Engineering Employers did was to dispel the popular delusion that whenever a trade union puts forward a demand, however extravagant, something ought to be conceded to the men in the interests of peace. Over and over again, nay, almost daily, during the strike, these employers were shrieked at for not conceding "something" to pacify the men. It is quite time this fallacy was disposed of. A man who demands your coat is not necessarily entitled to your vest. The making of a demand does not of itself confer any right to consideration, and it is a mere abuse of the principle of arbitration to maintain that every time workmen make a claim on their employers their claim should be submitted to the respectful consideration and decision of third parties. No industry can be carried on under such conditions, and the recklessness with which the Engineer Employers were reproached for not conceding "something," and the rashness with which arbitration was offered and urged, proved how very necessary was the lesson which the Federation afforded.

On the machine question the employers had made up their minds that to concede the demands of the Amalgamated Society of Engineers would be to hand over the dominion in the engine-shops to the society, and that they very properly declined to do. On the other question they knew that they could not make any reduction in the working day without throwing themselves out of the international race of competition,—and that they were not prepared to do. No compromise was possible, and, therefore, neither arbitration nor mediation could have been effective. Accompanying these questions were questions of workshop management, which could only be adjusted by the disputants themselves. On both questions, at the very outset, and before either was made the actual *casus belli*, the employers made it clearly and definitely known that they could not, and would not, concede anything. Yet, in

spite of positive assurances and convincing arguments, the men went out on strike, and involved the whole British nation in turmoil and in commercial loss for seven months. Was that a good reason why they should obtain something else? They failed to make out a case for their claims; they were from the first condemned at the bar of public opinion; and they deserved no consolation prize for failing to obtain what they had no right to have. It is too common a practice among combinations of workmen to make extravagant claims in order to obtain something less than they ask, and thus to deceive the public by appearing to be conciliatory. The engineer employers knew and declared that the demands of the Amalgamated Society of Engineers would be destructive to the industry, and, therefore, they refused the demands, and also declined to make any concession in lieu of them. And thus they taught the trade unions a valuable lesson,—that in future they are not to expect that whenever they choose to ask anything not justly due to them they will surely obtain something or other to help to "make them good."

Another thing which the engineers' strike demonstrated, for the benefit of politicians and economists, is the futility of State interference in industrial disputes. In this particular dispute there was nothing to arbitrate about, and, therefore, there was no room for mediation. It was, of course, the case that the actual matters at issue were more and greater than the ostensible cause of the strike. The struggle was a trial of strength, and it could be terminated only by the surrender of the one side or the other. Nevertheless, the Board of Trade did attempt to come between the contestants. It could do nothing to effect a settlement, because a settlement was possible only on the terms laid down by the employers, who had proved themselves to be the stronger party. But what the intervention of the Board of Trade did was to inspire the strikers with the belief, or at all events the hope, that the State would, sooner or later, bring pressure to bear on the employers to terminate the battle by yielding to them at some point. Sustained by this belief, or hope, the trade unions carried on the war for several weeks longer than they would otherwise have done. The Board of Trade thus really was the cause of the waste of many thousands of pounds to the societies, and of increased loss to the employers and to the trade of the country. So far from facilitating a settlement, the well-intentioned efforts of several members of the Board served only to retard one, and to make it more difficult; for the men were beaten and on the verge of surrendering when the Board stepped forward with suggestions that were resented on the one side and misunderstood on the other. Doubtless the Board of Trade was doing only what it is required to do under the provisions of the Consolidation Act, but this is just another example of the futility of that feeble Act of legislation, and it affords a warning against further attempts to drag the State into industrial disputes. Where the Board of Trade might have been useful in the case of the engineering dispute was in obtaining information regarding the hours of labour, the rates of wages, and the conditions of labour in the engineering industries of other countries, and in collecting particulars of the exports and imports of machinery all over the world. But in such educative service the Board entirely failed.

What lesson, then, did the men derive from the struggle and its result? This is not an easy question to answer, because working-men, as a body, are inarticulate, and one has learned to distrust the utterances of the professional representatives of labour. As far as can be gathered from conversation with trade unionists, the abiding feeling seems to be that it was a great mistake of the Amalgamated Society of Engineers to have raised a quarrel with the employers about an eight-hour day, for which there was, and is, no special desire in the provinces. There is also, perhaps, a glimmering, though mistaken, belief among the men of the Society that if they had not challenged

combined resistance on this point they might have secured for themselves larger control of machine tools. What the leaders and officials of the contesting trade unions think of the struggle and its issue is another matter. It is much to be feared that they paid more attention to the tactics than to the ethics and economics of the contest.

Mr. Barnes, the general secretary of the Amalgamated Society of Engineers, in an address on "The Struggle in the Engineering Trade," which he began delivering in various parts of the United Kingdom soon after the settlement, said that the employers "used their organisation for the purpose of getting complete mastery of their workshops." But in commenting on this success, Mr. Barnes added the charge that "in consequence of being in the Federation" some employers had come to assume a "contemptuous disregard for operatives, for trade unions, and more particularly for the Amalgamated Society of Engineers."

Such statements are wholly unfounded. It should rather be said that "in consequence of being in the Federation," the engineer employers obtained a better knowledge of the militant quality of trade unionism than ever they had before; but to say that any employers of skilled labour have acquired a contemptuous disregard of their operatives is untrue, as Mr. Barnes has probably learned during his later intercourse with the Federation. The engineer employers are as anxious for, and as appreciative of, good workmen as ever they were,—indeed, they have learned to value them more highly. It is but right to say, however, that Mr. Barnes did not blame employers alone, but acknowledged wrong-doing on his side of the struggle, admitting that things had been done and demands made on the part of the operatives of which he himself could not approve. And since employers have gone in for organisation, Mr. Barnes declares, "trade unions will have to work more and more for increasing the area of collectivist employment, and for the abolition, as much as possible, of sectionalism." What trade union leaders now see is that "trade unionism on the old lines has done good work, but workers will now have to recognise that isolated trade unions on the old line are not sufficiently effective in the changed conditions now existing; employers are organising, amalgamating, and federating all around, and workmen, too, will have to organise on a wider basis." What they do not perceive is that if trade unions organise themselves into being a more intolerable burden on industry than they have been in the bitter past, employers may federate themselves into the ability to refuse to employ all trade union labour on any terms. The leaders in the movement for the federation of trade unions would do well to remember this.

The terms of settlement which brought to a close the memorable struggle between the Amalgamated Society of Engineers and the Engineering Employers' Federation provide a full and frank recognition of trade unionism, and of the right of workmen to combine for the furtherance of their own interests. Some may think that in this the employers were too complaisant; but, nevertheless, the fact remains. From the outset of the struggle, and all through it, they disclaimed any desire or intention of "smashing the unions," or of interfering with trade union management. But neither will they have any trade union interference with the management of their business. Hence the preamble to the treaty of peace, which set forth the general principle of freedom:—

"The Federated Employers, while disavowing any intention of interfering with the proper functions of trade unions, will admit of no interference with the management of their business, and reserve for themselves the right to introduce into any federated workshop, at the option of the employer concerned, any condition of labour under which any members of the trade unions here represented were working at the commencement of the dispute in any of the workshops of the Federated Employers; but in the event of any trade union desiring to raise any question arising therefrom, a meeting can be arranged by applica-

tion to the secretary of the employers' local association to discuss the matter.

"Nothing in the foregoing shall be construed as applying to the normal hours of work or to general rises and falls of wages, or to rates of remuneration.

"*Note.*—No new condition of labour is introduced or covered by this clause. It simply provides for equality of treatment between the unions and the Federation by reserving for all the members of all the trade unions, as well as for all the Federated Employers, the same liberty which many trade unionists and many employers have always had.

"Special provision is made in the clause and in the subsequent 'Provisions for avoiding future disputes' to secure to workmen, or their representatives, the right of bringing forward for discussion any grievance, or supposed grievance."

It will be seen that while thus establishing the principle of absolute freedom in the management of their works, the employers distinctly recognised the trade unions as competent bodies. Much discussion took place at and during the closing conferences as to what do, or do not, constitute the "proper functions" of trade unions. But whatever these functions may be, the employers were resolved to secure freedom of action for their workmen as well as for themselves. Hence, the very first conditions of settlement thus assured freedom of employment:—

"Every workman shall be free to belong to a trade union or not, as he may think fit.

"Every employer shall be free to employ any man, whether he belong or not to a trade union.

"Every workman who elects to work in a Federated workshop shall work peaceably and harmoniously with all fellow employees, whether he or they belong to a trade union or not. He shall also be free to leave such employment, but no collective action shall be taken until the matter has been dealt with under the provisions for avoiding disputes.

"The Federation do not advise their members to object to union workmen, or give preference to non-union workmen.

"*Note.*—The right of a man to join a trade union if he pleases involves the right of a man to abstain from joining a trade union if he pleases. This clause merely protects both rights. The Federation sincerely hope that a better understanding will prevent any question of preference arising in the future, and advise members not to object to union workmen."

Where the trade unions were most jealous of their functions was in connection with the "rating of workmen," or, in other words, the adjustment of wages to capability. For an employer to pay a man just what he is worth is hardly in harmony with the general design of trade unionism, which is to equalise wages. Upon this arose the question of "collective bargaining," and the functions of a trade union to make wage-bargains applicable to all their members. The employers had no objection in the world to trade unions arranging among themselves what wages they will work for, but they properly objected to be compelled to pay these wages, whether they are just or right and proportionate to the market or not. For the trade unions to require employers not to employ men at lower wages than the trade unions fix for their own members is to ask employers to enforce the rules and regulations of the unions. This has been sometimes done in the past, but can never be done in the future, wherever employers are federated. While recognising the principle of "collective bargaining," the Engineering Employers hold themselves free to make their own bargains with their individual workmen. This is established by the fourth clause of the agreement:—

"Employers shall be free to employ workmen at rates of wages mutually satisfactory. They do not object to the unions or any other body of workmen in their collective capacity arranging amongst themselves rates of wages at which they will accept work, but while admitting this position, they decline to enforce a rule of any society, or an

agreement between any society and its members.

" The unions will not interfere in any way with the wages of workmen outside their own unions.

" General alterations in the rate of wages in any district or districts will be negotiated between the employers' local association and the local representative of the trade unions or other bodies of workmen concerned.

" *Note.*—Collective bargaining between the unions and the employers' association is here made the subject of distinct agreement.

" The other clauses simply mean that as regards the wages to be paid there shall be (1) freedom to the employer; (2) freedom to the union workmen, both individually and in their collective capacity,—that is to say, 'collective bargaining' in its true sense is fully preserved; and (3) freedom to non-unionists."

Thus only general alterations of wages, up or down, are to be negotiated between the organised bodies. But fuller regard is paid to the "proper functions" of trade unions in the final clause of the agreement, which makes provision for the avoidance of future disputes:—

" With a view to avoid disputes in future, deputations of workmen will be received by their employers, by appointment, for mutual discussion of questions in the settlement of which both parties are directly concerned. In case of disagreement, the local associations of employers will negotiate with the local officials of the trade unions.

" In the event of any trade union desiring to raise any question with an employers' association, a meeting can be arranged by application to the secretary of the employers' local association to discuss the question.

" Failing settlement by the local association and the trade union of any question brought before them, the matter shall be forthwith referred to the executive board of the Federation and the central authority of the trade union; and pending the question being dealt with there shall be no stoppage of work, either of a partial or general character, but work shall proceed under the current conditions.

" *Note.*—A grievance may be brought forward for discussion either by the workman individually concerned, or by him and his fellow workmen, or by the representatives of the union."

The provisions of this clause have proved most effective in preserving harmonious relations and preventing rupture ever since they were drafted. Disputes have occurred, of course, as disputes must always occur in such a great industry with so many branches and complications; but in every case they have been amicably and expeditiously settled by the machinery provided, and by the zealous and faithful co-operation of the Amalgamated Society of Engineers in giving effect to it. Thus the Engineering Employers have safeguarded their own rights, secured their independence, and protected non-union labour, not only without "smashing the unions," but by actually placing the unions in a more clearly defined position.

From the industrial point of view, then, the greatest gains of the engineers' strike were this determination of the freedom of employment in the engine-shops, and the recovery by the employers of the management of their own works. This last was a much more important gain than the casual observer may suppose. Practically, the control of output had fallen into the hands of the trade unions, and the vigilance of the Amalgamated Society of Engineers' spies, or "shop stewards," rendered the most conscientious foremen and the most energetic managers powerless to obtain better results than the society officials chose to allow. There was perpetual interference with non-union labour, with industrious apprentices, with machine-tenders who dared to look after more than one machine at a time, however simple it might be, with machine men rash enough to do a hand's turn apart from their machines, and with the general routine of the shop. All this came to an end. The master became again master in fact as well as

in name, and though he respects his man's union, he will not allow that union to come any more between him and his employees.

But more than that. The vexed question of overtime has been placed on a clear basis. Overtime labour is dear labour, and no employer likes it if it can be avoided. But overtime working in the engineering industry is at times absolutely necessary, and by the arbitrary stoppage of overtime in cases of emergency Amalgamated Society of Engineers' officials had frequently in the past inflicted serious loss and damage on employers. The agreement now is that, in ordinary circumstances, overtime is not to exceed forty hours per month after full shop hours have been worked. But there is no restriction of overtime in cases of breakdown in plant, repairs of ships or works, trial trips, and in "cases of urgency or emergency." All other restrictions are removed, and this agreement is notable as being the first attempt to regulate and prevent excess of overtime in the industry as a whole.

Of greater importance even than this was the settlement of the long-standing and much-vexed question about the working of machine-tools. Two things had long been contended for by the Amalgamated Society of Engineers,—that machine-tools should be worked exclusively by their members, or by members of some other society of skilled workmen; and that machines should be rated to pay a certain fixed wage, irrespective of the capacity of the operator. The employers can train unskilled men, and even boys, to tend many of the modern and improved kinds of machine-tools in use, and they can obtain most excellent results from such operators. Moreover, they have, as a rule, plenty of employment more befitting the ability of a skilled mechanic than the mere watching and tending of an automatic machine. To pay the wage of a skilled artisan for the work of a labourer is an extravagance that the industry cannot afford. The same kinds of machine-tools are used in the United States, in Germany, in France, and in Belgium, and in those countries the machines not only run several hours more per week than in Great Britain, but a machine man will, in those countries, attend to two, or four, or six machines for less wages than an Amalgamated Society of Engineers' man required for attending to only one machine in Great Britain. If he attempted to handle more than one he was "warned," fined, and, if persistent, expelled by his society. All this was put on a satisfactory basis by the sixth clause of the agreement, which runs:—

"Employers are responsible for the work turned out by their machine-tools, and shall have full discretion to appoint the men they consider suitable to work them, and determine the conditions under which such machine-tools shall be worked. The employers consider it their duty to encourage ability wherever they find it, and shall have the right to select, train, and employ those whom they consider best adapted to the various operations carried on in their work shops, and will pay them according to their ability as workmen.

"*Note.*—There is no desire on the part of the Federation to create a specially favoured class of workmen."

The free selection of the most suitable labour for machine-tools thus secured has given the employers the full use and productive powers of their machines.

And yet another valuable result of the struggle was the extension of the practice of piece-work in the engineering industry. Against piece-work the Amalgamated Society of Engineers had always previously been arrayed. In fact, the amalgamation of the old societies of engineers was formed with the avowed object of abolishing piece-work, and the very first strike of the Amalgamated Society of Engineers was in this connection. Rule 39 of the society is very severe as to piece-work. It enacts that:—"(1). Any member asking for, or taking, work by contract or piece-work in any firm or factory where piece or contract work does not at present exist, * * * * shall, for the first offence, be fined 20s., for the second 40s., and for the third, be expelled

from the society; and in no case shall piece-work be engaged in any firm or factory where it does not at present exist." And again "(3). Any member taking work by the piece or contract, and not sharing equally in proportion to his wages any surplus made over and above the weekly wages paid to members and other persons working on such job, shall be summoned before his branch or branch committee, and if he does not comply with the above regulation he shall be fined in the first instance 20s., second 40s., and in the third instance be excluded, subject to the approval of the council."

This traditional and constitutional opposition of the Amalgamated Society of Engineers to piece-work was, however, only that of the society as a body. That is to say, the objection was largely an administrative one, because under piece-work the executives have not the same control over production as under time wages, and their hold over their own members is thus weakened. But the men themselves, the men of real skill and industry, like piece-work (at all events, in some departments, for it is not so well adapted to all), because they can always earn more money at piece rates than on time wages at the so-called "standard" rates. Since the disclosures called forth during the strike it became evident that security against recurrence of the evils complained of, and a stimulus to all to effect the best results, would be obtained by the following conditions:—

"The right to work piece-work at present exercised by many of the Federated Employers shall be extended to all members of the Federation and to all their union workmen.

"The prices to be paid for piece-work shall be fixed by mutual agreement between the employer and the workman or workmen who perform the work.

"The Federation will not countenance any piece-work conditions which will not allow a workman of average efficiency to earn at least the wage at which he is rated.

"*Note.*—These are just the conditions that have been for long in force in various shops. Individual workmen are much benefited by piece-work. A mutual arrangement as to piece-work rates between employer and workman in no way interferes with the functions of the unions in arranging with their own members the rates and conditions under which they shall work."

In this connection the Federation intimated to the Amalgamated Society of Engineers that the general assurance given that the employers "do not want to introduce any new or untried conditions of work, and have no intention of reducing the rates of wages of skilled men, applies both to piece and time wages;" and that with regard to piece-work wages, "there is no intention of interfering with the usual practice of making extra payment for extra effort." This reform, as to piece-work, may be regarded as one of the most notable results of the strike. It marked a complete reversal of the traditional policy of the Amalgamated Society of Engineers, and was a change as valuable for the workmen as for the employers.

From what has been said, it will be seen that, bitter and costly as was the engineers' struggle, great good has come out of it. The whole industrial welfare of the British nation has benefited by the example and the endurance of the Federated Engineering Employers; the engineering industry itself was placed on just and rational conditions of management, leaving to both employers and employed their own legitimate rights; freedom was established in the management of the shops, the employment of labour, the use of machine-tools, and the application of piece-work, while the men are safeguarded, both as individuals and as trade unionists. Above all, one of the most valuable of her industries has been saved to the country by the discontinuance of conditions of working which were steadily playing into the hands of foreign competitors. And, perhaps, the best evidence of the wholesome, honest, and just character of the settlement is found in the fact that in the two years which have elapsed since the agreement was concluded, the affairs of

the industry have been carried on without interruption and with the most perfect good-will between employers and employed.

On more than one occasion serious difficulties cropped up, but in every case they have been arranged without anger and without stoppage of work. Needless to say, such a happy result could not have been attained without loyal co-operation on the part of both organisations.

THE OUTLOOK IN CUBA

FROM A COMMERCIAL ENGINEERING POINT OF VIEW

By E. Sherman Gould, M. Am. Soc. C. E.

THE close of the recent war between Spain and the United States left the Americans face to face with problems new in their experience and for the solution of which there was nothing in their past national life to prepare them. To-day the flag of the United States floats over distant possessions, and the American nation has become, by force of circumstances, the self-constituted guardian of the destinies of a neighbouring island in transition from a state of previous political servitude to one of which the character is yet to be determined. That the United States have so easily assumed their new responsibilities, and, on the whole, so well discharged them, is a proof, if other proofs were needed, of the singular adaptability of the American form of government to all conditions and circumstances in which the nation can be placed.

In Cuba there are two propositions to be considered,—the political and the commercial. Although separate in character, they are intimately correlated. The correlation, be it noted, is closer in regard to the dependence of the commercial proposition upon the political than *vice versa*. No general development of the island's resources is possible until a political and legal status is created, sufficiently intelligent, firm, and stable to permit of giving good title in the conveyance of property, the granting and guaranteeing of franchises, the certainty of realising upon pledged securities, and the right to sue and be sued. Cuba herself, in her past history, offers an object lesson in this respect. While the neighbouring South American republics have never enjoyed peace or prosperity, owing to incessant political upheavals, Cuba achieved and maintained a marvellous commercial development because she was under a form of government, wretchedly bad, it is true, but possessing the essential element of solidity. In this respect it may be truly said that any government is better than none.

The writer's aim is to give in this paper a brief review of some of the principal data of Cuba's commercial problems, as he understands them. No statistics shall be given, nor details; they would lead too far, and they may be found in well-digested masses in the two admirable volumes, "Commercial Cuba," by Mr. W. J. Clark, and "Industrial Cuba," by Mr. R. P. Porter, and other publications of minor value.

From one cause and another the capital and energy of the island have been for many years concentrated upon sugar and tobacco. Of these two products the latter enjoys the advantage of being a specialty. That is to say, the finer grades of the Pinar del Rio tobacco are different from, and better than, that raised in any other part of the world.

Cuban sugar enjoys no such distinction. The advantages which Cuba possesses as a sugar-producing territory depend upon her exceptional facilities for cheap production. Sugar of exactly the same grade can be made elsewhere, but probably nowhere else are the essential conditions for cheap production so favourably combined as in Cuba. Under these circumstances, and despite the exclusive and special character of her tobacco, Cuba's sugar exports prior to the revolution probably quintupled those of tobacco. Under the stimulus of the short-lived reciprocity treaty between the United States and Spain they reached their zenith, with still wider horizons opening out; but the bright prospect was abruptly extinguished by the abrogation of that treaty, oddly enough by a free trade administration in the United States. It is probably a sober fact, and not a mere flight of fancy, to say that the stagnation of business which immediately followed the annulling of the treaty paved the way for, if it did not actually lead to, the revolution which shortly after broke out in Cuba.

In the future and under favourable circumstances, many other of the resources of the island will undoubtedly be developed, and it will be a source of great commercial strength that such varied development should take place; but, for the time being, Cuba's sugar must be regarded as her commercial stronghold and the backbone of her prosperity. Unhappily, this vast industry, reaching, prior to the war, an annual value of over fifty million dollars (£10,000,000), built up with so much labour and intelligence, and representing the investment of a vast sum, has been practically destroyed, and must be raised up again from the very ground, requiring the expenditure of an amount of capital measurably comparable to that originally invested. Nor can this be done by beginning in a small way. Sugar cannot be profitably made on a small scale. To properly install an "Injenio" requires an outlay of from $300,000 to $500,000 (£60,000 to £100,000) at least.

In early years each plantation ground its own cane and turned the juice into sugar and the bye-products of molasses and rum. At present the best practice is to keep the two operations of raising the cane and making the sugar separate. Hence, the tendency is towards the installation of large "centrals," where cane is purchased from tenants and "colonies" and made into sugar.

Replanting the cane fields burned over during the recent revolution is already commencing, for this can be done without much outlay of capital; but rebuilding and re-equipping the works is progressing very slowly, being held back for want of money. Unwise legislation in extending mortgages and payment of interest on them, joined to uncertainty regarding the political future, has struck a serious blow to the borrowing powers of operators, by discrediting the security offered. Perhaps the greatest hope for the revival of this industry lies in the buying up, at low figures for cash, of the wrecked and abandoned centrals by foreign capitalists.

The writer will here take leave of the subject of sugar, with the parting word that no substantial progress can be made towards restoring Cuba to the flourishing condition which she enjoyed during the short period just before the breaking out of the rebellion when the reciprocity treaty was in full force, until millions of capital can be safely invested in rehabilitating her abandoned "centrals."

The next subject which demands attention is the railway system of the island. The existing roads were greatly wrecked and their business paralysed during the war. At present the system needs not only reconstruction and reorganising, but also extension. The western part of the island, from Pinar del Rio to Santa Clara, is tolerably well provided with roads, both longitudinal,—that is, running east and west, or lengthwise of the island,—and cross-country,—that is, running north and south from water to water. At the extreme easterly end there are a few short lines about Santiago, but between Santa Clara and Santiago, a distance of about 300 miles, there is no communication

by rail, so that the easterly end of the island is practically isolated from the westerly end by land and accessible only by sea. The practice in Cuba has been to connect the principal interior towns directly with their corresponding seaports, almost entirely neglecting inland inter-communication by rail, the theory being that the one thing needful was to reach a shipping point by the shortest cut, oblivious of the fact that in railroading the longest way around is sometimes the shortest.

The most pressing need in the railway development of the island is, therefore, the so-much-talked-of "central railway," which shall unite Santa Clara with Santiago. The construction of this road, even upon the most skillfully selected location, would involve grave engineering difficulties, to be overcome only by large expenditure, because the line would cut across all the natural obstacles offered by a rough and broken country. In a word, the road would be very expensive to build, but whoever owned or controlled it would be railway king of Cuba.

When existing rules, regulations and practice shall have been so modified as to permit city governments to give franchises for water-works, trolley lines and other much-needed municipal improvements, a vast field will be opened up for enterprises of this class. Hitherto the obstacles interposed by military authority have rendered progress in this direction impossible. The writer is not at present discussing the wisdom of this course, but merely stating a fact.

The necessary elements for the restoration of prosperity in Cuba are, first and foremost, government and equitable laws. These being secured, the next requisite is plenty of cash capital. This is an ineludible necessity. No amount of Yankee ingenuity or Anglo-Saxon energy can accomplish results unless backed up by cold cash. It is often mistakenly supposed that the introduction of American business methods is all that is needed to start the hey-day of prosperity in Cuba, and that men whose only capital is their alleged brains and energy can float successful enterprises on a paper basis. The day has gone by when such ideas can prevail. It is money, not methods, that is needed. Some free-lances, with nothing to lose and everything to gain, will, doubtless, make lucky strikes; but their individual success will tend but little to the general prosperity.

It is not to be gathered from the above that capital must await the full consummation of a fixed rule in Cuba. Step by step it will follow the advance of every measure making for good government, treading closely upon the heels of every point gained in that direction, and doubtless great profit will attend the earlier and bolder investments. Indeed, the entrance of large moneyed interests and the establishment of a strong government will react upon one another, and large *bona fide* investments will demand and receive strong protection.

The question that is most interesting at present is, who, besides Cuba herself, is to be benefited by all this? Shall it be Americans? It seems to be taken for granted that the Americans who have opened up these opportunities are the ones to be benefited thereby. This is by no means certain. It is quite possible that to them may be applied the proverb:—"*Sic vos non vobis.*" British and European capitalists, traders, and industrials also have their eyes fixed upon the "Pearl of the Antilles." They have many advantages over Americans. They have more money and are, therefore, bolder, quieter, and swifter operators, and have already longer experience in the foreign field. Their merchants, operating upon a carefully studied system of long credits, will beat the American competitor who insists upon cash payments and even payments in advance. They thoroughly understand the grand tactics of commerce, while Americans adhere, in the foreign field, to the policy, very wise in the home market, of presenting the goods with one hand and the bill with the other. No extensive business can be done in the Spanish-speaking countries on this basis.

The existing railway system of Cuba

has already practically fallen into British hands. No doubt the present controllers will play a waiting game, contenting themselves with proprietorship and, perhaps, 1½ per cent. on the investment while the future is being shaped. The cigar factories are understood to have gone the same way. When foreign capitalists enter into such heavy operations they take a far look ahead and stand prepared to offer spot cash for lowest figures and war risks. Also, when determined on making a venture, they take lowest figures, instead of offering them. At the present time, in Cuba, they have, too, the great advantage over Americans that, in case of need, they can invoke the aid of their governments, whereas Americans cannot appeal, except in a very roundabout, and usually unsuccessful, way, against their own authorities.

The interregnum which has prevailed since the American occupation, has had a most happy effect. It is a non-committal condition, giving time for natural forces to get in their silent and always beneficent work. While it lasts, the United States exercise an unlimited control over the destinies of the island, more absolute by far than if it were actually annexed. There is a strong promise that this control will be exerted wfth wisdom and lead to the best results.

A PLANT OF NINE SINGLE-ROPE ROPEWAYS IN THE NORTH OF SPAIN, HAVING A CAPACITY OF 300 TONS PER DAY. ERECTED BY BULLIVANT & CO., LTD., LONDON

PROGRESS IN AERIAL TRANSPORTATION

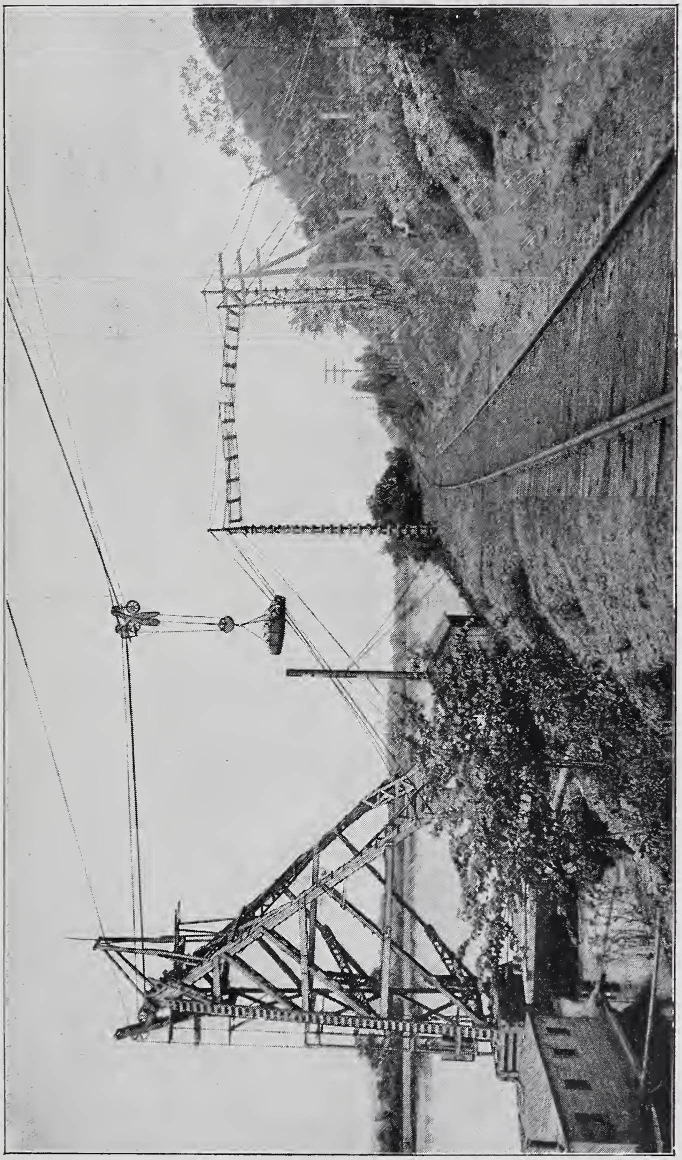
By William Hewitt

THE time was when aerial transportation was looked upon as a novelty; it has, however, become common enough now, so that it not only no longer excites the curiosity of intelligent people, but its adaptabilities and advantages are so well recognised that it has come to be properly regarded as a legitimate and economical method of transportation.

The saving effected over a surface line in grading and trestle work is an advantage that will appeal strongly to many, and another advantage is that the points of loading and discharge may be reached directly, thus avoiding a rehandling of material which would be necessary with a surface road. Wire rope transportation heretofore has found its widest application in mountainous localities, and more especially in mining regions, where frequently it has proved to be the only practical way of utilising other than animal power for conveying ores from the mines to the mills or railways, as the case may be, and also for carrying back freight to the mining camp.

Its adaptabilities, however, for less rugged localities are beginning to be quite as well appreciated, and this is more especially true of localities where intervening hills and ravines would be an objection to any kind of surface line on account of the circuitous and costly detour necessary, and particularly where rivers have to be crossed, and where the cost of a bridge would be a serious bar to the building of a railway, even though the contour of the ground might favour the construction of such a road.

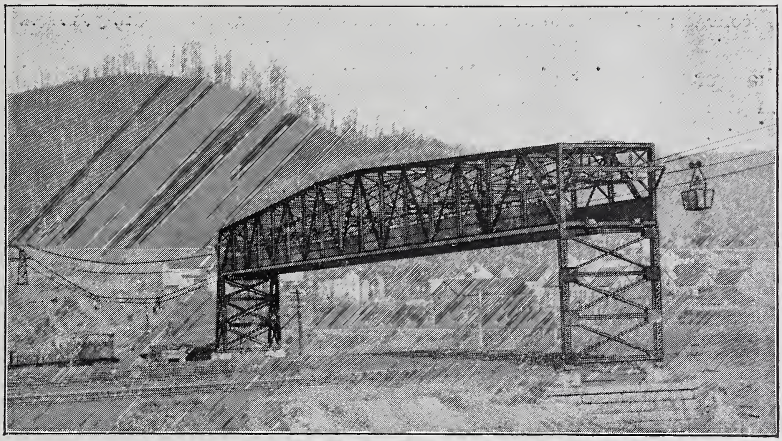
Another instance is where already existing railways have to be crossed and the right of way for a surface line would be out of the question. In such cases it is common, as a safeguard against accident, to protect the tracks in some way, either by simply suspending a wire



A CABLE HOIST-CONVEYOR WITH GUARD NET OVER RAILWAY LINE, INSTALLED BY THE TRENTON IRON CO., TRENTON, N. J., U.S.A.

A ROPEWAY IN THE PYRENEES, WITH 1200-YARD SPANS. DESIGNED FOR CARRYING LOADS OF HALF A TON. INSTALLED BY MESSRS. BULLIVANT & CO., LTD., LONDON

net over them, or by a bridge, as in the case of main lines, where an accident might result in serious injury. The view on page 503, of a cable hoist-conveyor at Britt's Landing, Wis., U. S. A., built for the United States Government, shows a guard net across the Chicago, Burlington & Northern Railroad, and the view on this page, representing a wire rope tramway recently installed by the Cambria Steel Company, at Johnstown, Pa., shows a guard bridge across the main line of the Pennsylvania Railroad. In the latter instance the bottom and about three feet of each side of the bridge are encased in sheet iron, an unusual precaution. The span across such a line cross their property. This last-mentioned difficulty will be more readily appreciated when it is understood that wire-rope tramways must be run in straight lines, and that while it may be practicable to make bends or angles in the route, stations are required at these points, with men in attendance to pass the buckets around the deflecting sheaves, which adds both to the first cost and to the cost of operating. Bends are objectionable on this account. In some places laws have been passed regulating the construction of wire-rope tramways, and in one instance the law provides for the condemning of property as need may be.

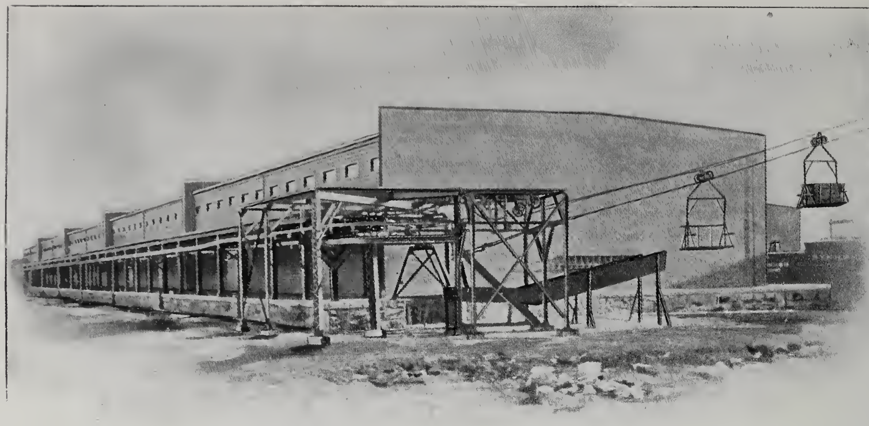


A GUARD BRIDGE FOR A ROPEWAY ACROSS RAILWAY LINES

the tracks is 220 feet. On page 506 also is shown a guard bridge across a country road.

That the merits of aerial transportation may have been slow to gain due recognition in some places may be attributed to the accessibility of railways; the readiness of railway companies to extend branch lines to newly developed sections along their route, and to points where the amount of freight will warrant the building of a branch line; the difficulty of obtaining the right of way in many instances for an aerial line, owing to the impression that such lines are detrimental to property interests; and the natural objections of those who may not be benefited in any way by having

The difficulty of making bends in a wire-rope tramway has resulted in an effort on the part of some to devise means whereby the tramway cars may be passed around the deflecting sheaves at such bends without having to detach them from the moving or traction rope. The reason for detaching the cars in the double-rope system of wire-rope tramways will be clearly understood from an examination of the car shown at the top of page 511. This consists of a bucket or other receptacle for holding the material to be transported, suspended by means of a hanger from a carriage that runs on the track cable, and a grip for fastening the car to the traction rope. The grip, it will be observed, is attached



A DOUBLE-ROPE SYSTEM WITH A RIGHT-ANGLE TURN AT THE WORKS OF THE PLYMOUTH, MASS., CORDAGE CO. ERECTED BY THE TRENTON IRON COMPANY, TRENTON, N. J., U. S. A.

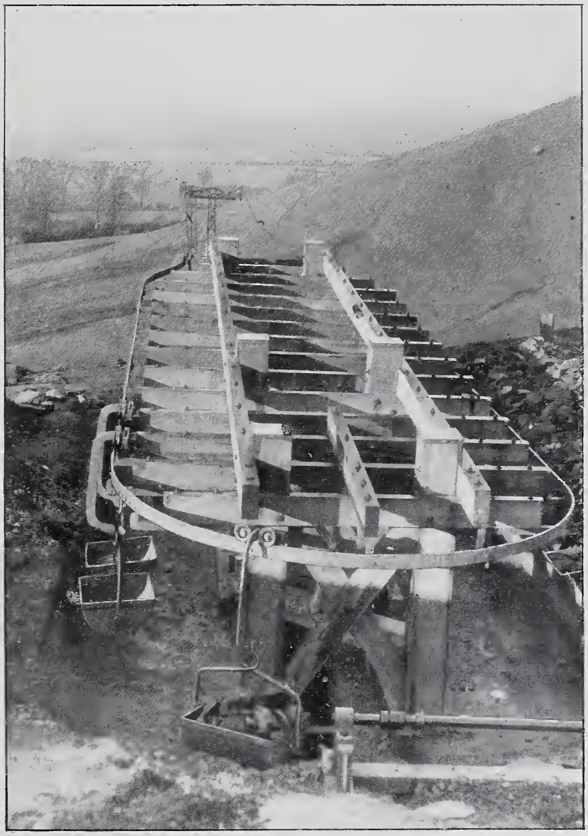
to the hanger at a point about midway between the carriage and the bucket. In making a bend the traction rope, of course, must be guided around the angle by sheaves, both on the out-going and in-coming sides, and if the grips were not detached, they would strike the flanges of the sheaves on the convex side of the bend, and on the opposite side the hangers would come between the rope and the sheaves, which would lead to trouble even if it were practicable to make a grip that would work in contact with the sheaves.

This difficulty has been overcome in a measure by attaching the grip to the carriage in the manner shown in the diagram on the same page, which illustrates a style of car used on a line recently installed for transporting baled hemp from

A GUARD BRIDGE OVER A COUNTRY HIGHWAY

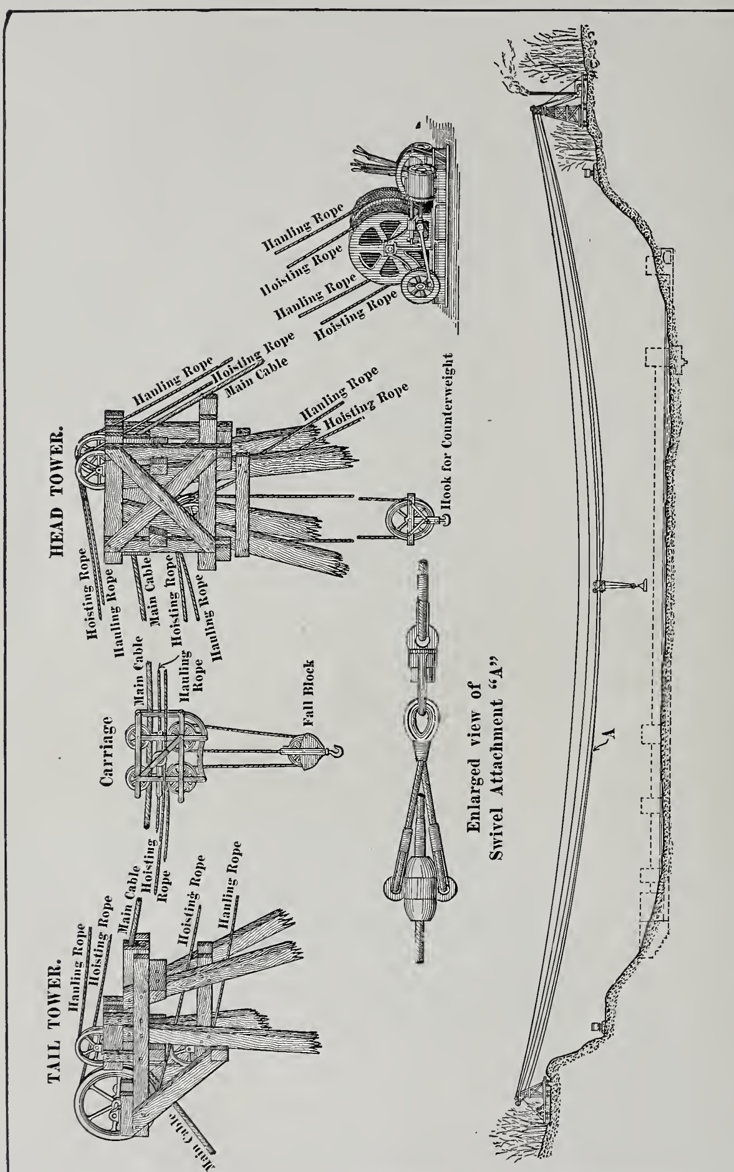
a warehouse to a cordage factory. The traction rope in this case runs above the track cables, this arrangement being adopted owing to a right-angle bend which was necessary at the end of the warehouse, around which the cars were to pass without detaching from the traction rope. A view is also given on page 506 of the iron structure at this point, and the warehouse. Along the warehouse for a distance of 500 feet there is an arrangement of shunt rails such that the cars can be loaded at any point desired, special apparatus being provided for releasing the traction rope while the cars are being loaded. The loaded cars from the warehouse, immediately after passing the angle station, ascend an incline of about 40 per cent. to a guard bridge 64 feet distant, spanning some railway lines. This plant has been in satisfactory operation for some time, and apparently indicates the solution of the problem of passing the cars automatically around bends, thus marking an advance in the adaptabilities of aerial transportation. This method of operating, however, where the traction rope runs above the track cable has its limitations. In cases where the downward pressure of the traction rope, for instance, is very great, as in crossing ridges and in surmounting steep elevations, it is not to be recommended, since the pressure may be so great as to throw the bucket around over the track cable, or at least into an inclined position, which would cause it to strike the timbers of the supports.

Another reason that aerial transportation may have met with slow favour is due to the fact that many of the earlier lines were of the single-rope type,* with one rope performing the dual function of supporting and propelling the loaded buckets. The principal merit of such a system is its cheapness. While these lines are well adapted to comparatively light duty, where the loads do not exceed 200 to 300 pounds, they have generally failed to meet the demand for increased and heavy outputs. For this reason, they now find a comparatively limited application. With the advent



TERMINAL STATION OF A SINGLE-ROPE PLANT

* In considering the merits of different kinds of wire-rope installation, it is to be borne in mind that the choice of system often must depend upon the particular conditions encountered and, as has been pointed out in a previous article on the subject in this magazine, it is only reasonable that each type of ropeway should be made for the situation in which the ropeway has to be used. No single type of ropeway can, therefore, be said to be the best for all places and all kinds of service. —THE EDITOR.



THE LAURENT-CHERRY SYSTEM OF CABLE HOIST-CONVEYORS WHICH DISPENSES WITH FALL-ROPE CARRIERS. INSTALLED BY THE TRENTON IRON CO., TRENTON, N. J., U. S. A.

of the double-rope system, however, in which loads are supported from stationary track cables, and moved by a light, endless traction rope, it is possible to handle loads up to a ton in weight, so that the capacity to handle a certain amount of material in a given time is very much greater, and has, consequently, widened the possibilities of aerial transportation, which is no longer looked upon as a system confined solely to mining operations, but is now employed with economy for transporting materials of all kinds, under almost every conceivable condition.

With single-rope lines, it is desirable in most cases, and especially where steep grades occur, to adopt a construction in which the bucket hangers are permanently attached to the rope by means of clips, such as used in what is known as the Hallidie system. This makes it necessary to load and unload the buckets while they are in motion, and to have automatic loading and unloading devices, so that it is not possible to run the rope at as high a speed as in the double-rope system, and a larger outfit of buckets is, accordingly, necessary. This fact has led to a demand for automatic loading and dumping arrangements; but these are not always to be relied upon for increased economy, because in most cases it is found desirable to have a man on the spot to watch and prod them occasionally in order to make sure that they will do their work without fail. It is, in fact, more from necessity than from any economy of labour effected that automatic loaders and d umpers are used in the single-rope sy stem. Still there are cases where such devices are desirable, and the tendency of improvement in wire-rope tramways and cable hoist-conveyors is in this direction.

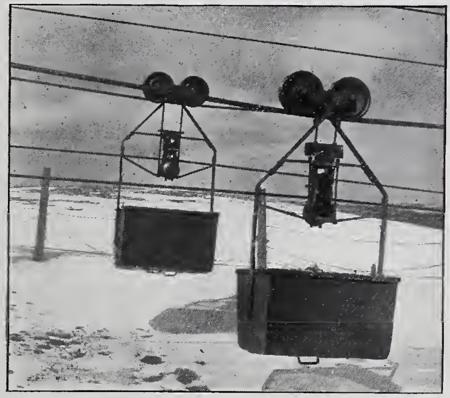
CABLE HOIST-CONVEYOR OF MESSRS. CORRY & LAVERDURE, PETERBOROUGH, CANADA

The foregoing remarks apply to that class of aerial lines known as wire-rope tramways, which are adapted more especially to long lines of transportation and comparatively light individual loads. Another class of aerial lines, known as cable hoist-conveyors, or simply as cableways, are distinguished from wire-rope tramways in the fact that they are adapted to handle single loads of considerable weight over comparatively short distances. These lines are usually

TAIL TOWER OF CABLEWAY USED IN MISSISSIPPI RIVER IMPROVEMENT, U. S. A., ERECTED BY THE TRENTON IRON COMPANY

designed to hoist as well as convey; hence the name, hoist-conveyor.

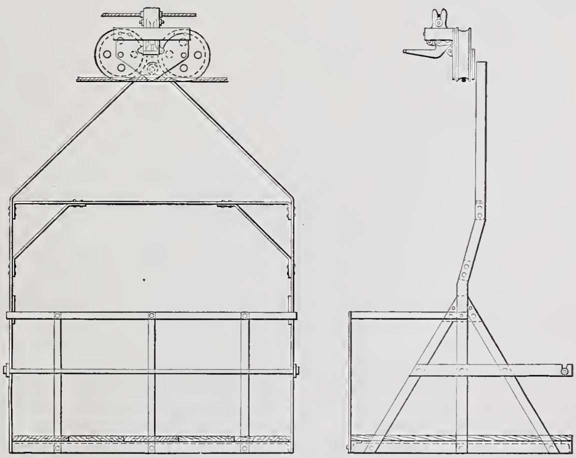
In lines of this class as heretofore constructed it has been necessary to use



THE USUAL METHOD OF BUCKET SUSPENSION ON A DOUBLE-ROPE LINE

mechanical appliances, known as "fall-rope carriers," for supporting the hoisting rope, which would otherwise sag unduly and prevent the descent of the unloaded fall-block. The first fall-rope carriers consisted each, simply of a couple of battens or strips, between which revolved two small rollers, the upper running on the track cable, and the lower supporting the hoisting rope. The carriers were connected by light chains which hung in festoons from one to the other and the tower head. These chains were cumbersome, to say the least, especially in long lines where a great many were required, and a source of constant trouble and annoyance from the fact that they were continually getting entangled and breaking, to say nothing of their interference with objects below the line. They have been superseded almost entirely by other forms, the best known of which is the carrier invented by Mr. Spencer Miller. The spacing of the Miller carriers is effected by a light rope, stretched between the towers or supports just above the track cable, attached to which at regular intervals are oval-shaped buttons, varying in size and corresponding in number to the number of the carriers. With the carriage at the tower from which the line is operated the carriers all rest on a pointed arm, or "horn," as it is termed, projecting from the rear of the carriage just above the track cable, the button rope passing between the strips forming the sides of the carriers. As the carriage is moved out it encounters the first button, which is of such size that it passes through all the carriers but the last, which drops off onto the track cable; the next button causes the next carrier to drop off, and so on. In returning, the horn of the carriage again picks up the carriers. These are a great improvement over the old chain-connected carriers, but they are objectionable owing to the constant hammering the buttons receive which knocks them loose or breaks them, and the abrasion of the button rope against the carriers, which quickly wear it out.

A system of cable hoist-conveyors



A METHOD OF BUCKET SUSPENSION ON A DOUBLE-ROPE LINE WHICH WILL PERMIT GOING AROUND CURVES

recently introduced and known as the Laurent-Cherry system, dispenses altogether with the use of fall-rope carriers. This is effected by an arrangement ex-

hibited in the diagram on page 508, which practically makes an endless circuit of the hoisting rope about sheaves in the two towers, to which circuit a short piece is apparently attached, though in reality it is simply an extension of one end, about 200 or 300 feet long, that leads to the fall-block supporting the load, or long enough to allow for the greatest vertical lift, and yet not so long as to overbalance the unloaded fall-block and prevent its descent. The fall-block is weighted sufficiently so that it will overhaul the short end of the hoisting rope. This rope is also counterweighted at the tower where the engine is, in order to preserve a uniform tension. In thus dispensing with fall-rope carriers the expense of maintaining them is not only obviated, but it becomes practicable to move the carriage at a much greater speed than is possible with lines using such devices, so that the capacity to handle a certain amount of material in a given time is correspondingly increased. A view is given on page 509 of such a line recently built by the Trenton Iron Co., of Trenton, N. J., U. S. A., for Messrs. Corry & Laverdure, Peterborough, Ontario, having a span of 350 feet and handling loads of 3½ tons. This line is used in the construction of a lock on the Trent Valley Canal.

Another line built for the United States Government is used in the construction of one of a series of four dams for the improvement of navigation in the Mississippi River between St. Paul and Minneapolis, under the direction of Major Frederick V. Abbot. A view of the tail tower of this line, on page 510, shows the large sheave around which the hoisting rope works. The tower, it will be noted, is mounted on trucks, the head tower being mounted in the same way, so that the entire line can be shifted as the work progresses. The clear span between the towers is 1150 feet, the longest yet made with a movable cable hoist-conveyor. The line is operated by an engine rated at 50 H. P., and is capable of handling loads of five tons at a speed of 800 feet per minute. A speed of 1200 feet, in fact, has been obtained without any appreciable vibration.

GAS OR ELECTRICITY FOR HEATING, LIGHTING, AND POWER?

By Alton D. Adams

SINCE the inception of electric lighting, it has been regarded by many as a necessary competitor with gas plants and a serious menace to the value of their investments. The more discriminating engineers and capitalists, however, have seen in gas and electric supply allies rather than competitors, and forms of energy adapted to supplement instead of to displace each other in public service. It may be safely assumed that the consolidation of vast gas and electric interests which has recently been effected in the city of New York, for example, marks neither the triumph of one kind of distribution over another, nor a contraction in the public service offered, but rather a wider application of each supply to the purposes for which it is best adapted.

Gas and electricity are each competent to supply, with more or less advantage, those great essentials of civilisation,—light, heat, and power. Owing to the conditions under which gas and electric service have usually been carried on, however, the relative advantages of each for the several wants of the public have not been properly presented. So long as the distribution of gas and electric energy remain in the control of competitive interests, in any community, the main effort of each will be aimed, as at present, to obtain the largest use of its supply in each mode of application. This process goes on without regard to the efficiency of each agent for a particular work, or even, in many cases, a uniform return on invested capital. Where, however, the production of electricity and gas comes under one management, the obvious tendency is to a system of rates calculated to yield a uniform per cent. of profit on all kinds of service. Such rates put consumers in a position to select each kind of service on its merits for the particular work desired.

The fact that either electricity or gas can be employed for light, heat, and power production creates no presumption of equal efficiency for each purpose; indeed, a little investigation shows quite the opposite to be the fact. Investments, fixed charges, and the labour of operation may, or may not, be equal per unit of light, heat, or power derived from electricity or gas. In any case it is quite certain that fuel, the constantly consumed base of each supply, must largely determine by its cost the limits of practicable application. While the fixed charges and labour vary with place and circumstances for electric energy and gas production, the fuel consumed and the possible effects in light, heat and power can be readily predicted. If it appears that some desired effects can be attained with gas by a much smaller expenditure of fuel than is necessary if electricity be employed, and that some other results require but a small fraction of the energy in electric form that must be consumed as heat from gas, it is reasonable to expect the application of each service to those purposes for which it is the more efficient.

To compare the energy of fuel involved in light from the gas flame and the electric lamp, heat by electric and gas stoves, or mechanical power with the gas engine and electric motor, the efficiency of energy production, as well as that of application to each case, must be known. It is, therefore, first desir-

able to note what portion of the energy from fuel combustion is delivered in gas or at dynamo terminals, and then to see what part of the work developed at lighting, heating, or power devices produces a useful effect. Two kinds of illuminating gas are used, based on different methods of production. Coal gas represents the vapours of bituminous coal, distilled in retorts at high temperatures; but as the solid carbon of the coal remains in the retorts as coke, the coal-gas contains only a small part, usually about one-fourth, of the total energy of coal. Owing to the small part of the coal energy that may be delivered in coal-gas, and to the time and space that its manufacture requires, water-gas has come into general use, either as a supplement to, or to displace, coal-gas production.

The general favour with which water-gas is now regarded by gas companies is largely due to the complete consumption of coal in the water-gas process and the increased per cent. of the coal energy imparted to the gas. For the production of water-gas hard coal and coke may be employed, as the carbon of the fuel is changed to the gaseous form by incomplete combustion. Water gas takes its name from the method of production, in which steam is forced through a bed of incandescent coal or coke. The steam is decomposed into its elements of oxygen and hydrogen, the oxygen uniting with the carbon of the coal or coke and the hydrogen remaining in a mixture of the resulting gases.

While water-gas, produced in this way, forms the base of most of the illuminating gas now distributed in large cities, such gas alone has only a slight illuminating power, and is generally charged with hydrocarbon vapours, mostly from petroleum. These vapours yield a large amount of heat on combustion and fully double the heating power of illuminating gas. Before treatment with vapours from petroleum, water-gas contains somewhat more than 50 per cent. of the heating capacity of the coal from which it is produced, and about 325 heat units per cubic foot. The hydrocarbons added to water-gas increase its heating capacity to from 650 to 750 heat units per cubic foot, and multiply its illuminating power many times. Nearly all of the fuel value of the hydrocarbon oils consumed is transferred to the gas, so that, as a complete product, illuminating water-gas contains fully 75 per cent. of the heat energy in the fuels required for its production.

The conditions of operation in electric stations are not such as to promote the highest economy of generating apparatus, owing to the large variations of public demand during each twenty-four hours. Owing to these changes in the demand for service, it is necessary, in steam-driven plants, to bring boilers into action during short periods and then to withdraw them, and also to operate engines on partial and variable loads. Some correction for the inefficiency incident to steam plants under these circumstances is offered by the storage battery, but it is by no means complete, both from the usual lack of sufficient battery capacity to give boilers, engines, and dynamos full and uniform loads, and because a loss of 15 or 20 per cent. must be encountered on all of the energy sent into the batteries.

If, therefore, efficiencies in an electric station are put at 80 per cent. for boiler plant, 15 per cent. for engines as to their delivered work, and 90 per cent. for dynamos, disregarding any battery losses, the resulting figures will be beyond actual attainment. The combined efficiency of these several elements, in electric generating plants, amounts to $0.80 \times 0.15 \times 0.90 = 10.8$ per cent., that is, the energy delivered as electric current at the connections to distribution lines cannot be more than 10.8 per cent. of that developed by the combustion of fuel. Comparing the figures just obtained with the result found for gas production, it appears that about seven times as much fuel must be consumed to deliver a unit of energy in the electric form as in gas. With this great advantage in favour of gas at the start, electricity must present some decided gain in application to warrant its extended use. Electric heaters are among

the very few devices that have a perfect efficiency. They deliver as heat, useful at least for general purposes, the equivalent of all the electric energy they consume. The very low efficiency above found for the production of electric energy unfortunately prohibits its extensive application to general heating, and limits it to those operations where convenience is of much greater importance than the actual energy consumed.

Allowing an efficiency of 50 per cent. for furnaces or steam and hot water heating plants in buildings, $0.50 \div 0.108 = 4.6$ times as much fuel must be consumed under boilers at an electric power station as is necessary for the building plant. Where gas is used for heating purposes, the products of combustion must be removed and new air constantly supplied to the flame, so that a part of the heat generated passes off in the draught. The proportion of the heat from gas thus escaping may be taken at 20 per cent., and the gas flame will then deliver $0.75 \times 0.80 = 60$ per cent. of the energy of the fuel for useful heating effect. It thus seems that the efficiency, referred to the total energy of fuel, is $0.60 \div 0.108 = 5.5$ times as great for the gas flame as for the electric resistance in general heating operations. Moreover, as the gas heater gives a useful effect of 60 per cent. of the total fuel energy, or as much as is obtained in the best class of steam and hot water heating plants, and twice as much as is usually yielded by ordinary stoves, its future as a common heating agent seems assured.

While electric motors do not have the ideal efficiency peculiar to heaters, they far surpass all other machines that produce mechanical motion in their ratio of delivered work to absorbed energy. Thus, while steam engines, at best, deliver the equivalent of but 15 per cent. of the heat in the steam entering them, and internal combustion engines can raise the figure to only about 25 per cent. of the calorific power of their gas or other fuels, electric motors easily exceed an efficiency of 90 per cent. in large units and range from 80 to 90 per cent. in small and medium sizes. Allowing for electric motors, on the average, an efficiency of 85 per cent., the ratio between their delivered mechanical energy and the heat of fuel is $0.108 \times 0.85 = 0.092$.

Gas engines, as just shown, have a low efficiency compared with electric motors, and in moderate sizes their delivered power can be fairly taken to represent 20 per cent. of the heat energy in the gas consumed. Even with this low efficiency of transformation they are able to show an output equivalent to $0.75 \times 0.20 = 0.15$ of the energy in fuel consumed at gas plants. As electric motors can deliver but 0.092 of the fuel energy, gas engines, doing $0.15 \div 0.092 = 1.6$ times as much work for the same amount of fuel, have a decided advantage in this particular.

In spite of some inferiority as to fuel efficiency, however, the electric motor seems certain to be preferred in very many cases where small powers are necessary, because of its freedom from dirt, noise, and odours, and also because of the small amount of room and attention required. The relative advantages of gas engines and electric motors, all things considered, seem to depend much on the amount of power wanted. When units are so large that economy of fuel is the first consideration, the gas engine is to be preferred, but for the greater number of small requirements the special features of electric motors make them more desirable.

The next field to be considered, that of artificial illumination, is the one where gas and electricity are usually thought to be most seriously in competition. Should it appear, however, on view of the facts, that one of these lighting agents is decidedly inferior to the other, from every point of view, it will be fair to conclude that the competition of gas and electricity in the production of light is largely based on certain unsatisfactory conditions of public service.

Relative advantages of gas and electricity for purposes of illumination may be compared on three points,—quality of light produced, effects as to ventilation, and the energy of fuel consumed to produce equal illumination with each. The effective decision concerning de-

sirability of either form of light must rest with the general public, and the fact that, besides the hundreds of thousand arc lamps which burn nightly, more than 15,000,000 incandescent lamps are consumed yearly in the United States alone, in spite of the greater cost of electric over gas lighting, certainly shows a decided preference for electricity. When gas and electric rates are so regulated that equal illumination may be had with either the gas flame or the incandescent lamp for the same price, then the use of the former for illuminating purposes seems certain to disappear.

When vitiation of the air in artificial illumination is considered, the incandescent lamp is ideal. Light from incandescent lamps being produced in a vacuum, without combustion, no gases are given off. The light of the arc lamp, like that from the incandescent, is given off by materials heated to whiteness by the electric current, and there is no appreciable effect in air vitiation. It is true that a very small amount of combustion takes place at the electric arc, not to cause the light, but as a result of the intense heat present. The small amount of impurity thrown off from electric arcs may be roughly judged from the fact that eighteen inches of round carbon rod, half an inch in diameter, supply the enclosed arc for more than one hundred hours, and even then quite a portion of the solid carbon remains in the form of dust. As a matter of actual experiment, the arc lamp generates about one-eighth of one per cent. of the carbonic acid given off by a gas flame of equal illuminating power.

In strong contrast with the harmless effects of electric lighting on the purity of air are the results of illumination by gas. The ordinary gas burner, consuming five cubic feet of gas per hour, gives off during that time about 2.6 cubic feet of carbonic acid, or four times as much as a man at rest. One thousand gas jets in a public audience room, therefore, vitiate as much air as 4000 men, and greatly increase the degree and expense of necessary ventilation.

Coming to the important question of amount of light produced for energy consumed, the electric arc easily leads in efficiency, with an average consumption of one watt-hour, or 3.4 heat units, at the lamp per candle-power hour. Incandescent lamps come next in efficiency, using 3.5 watt-hours, or 12 heat units, per candle-power hour. Assuming that five cubic feet of gas, with 700 heat units per cubic foot, will supply a burner giving 18 candle-power during one hour, the expenditure of heat at the gas flame per candle-power hour amounts to $(700 \times 5) \div 18 = 194$ heat units. The consumption of energy at the lamp, per candle-power given off, with the gas flame is $194 \div 12 = 16$ times as great as at the incandescent lamp, and $194 \div 3.4 = 57$ times as great as at the electric arc. Since gas contains 75 per cent. of energy in the fuel used for its production, the heat units of that fuel per candle-power hour must be $194 \div 75 = 258$ heat units.

Electric energy was found equivalent to 10.8 per cent. of that in the coal necessary for steam boiler furnaces. For arc lamps the coal consumed must, then, contain $3.4 \div 0.108 = 31.4$ heat units per candle-power hour at arcs, and with incandescent lamps the fuel burned under the boilers develops $12 \div 0.108 = 111$ heat units per candle-power hour. For the same illumination, therefore, the gas flame requires $258 \div 31.4 = 8.2$ times the fuel necessary for electric arcs, and $258 \div 111 = 2.3$ times the fuel for incandescent lamps.

Unless there is a much greater difference in the items of labour and fixed charges between the production of electric energy and that of gas than is believed to exist, the facts presented, therefore, warrant the following conclusion:—The great bulk of heat derived from public supply should be effected by gas. Power in small units is best distributed electrically, but for large units gas is more suitable. For purposes of illumination electric energy is much superior to gas from every point of view, and may be expected to generally supersede it for that purpose.

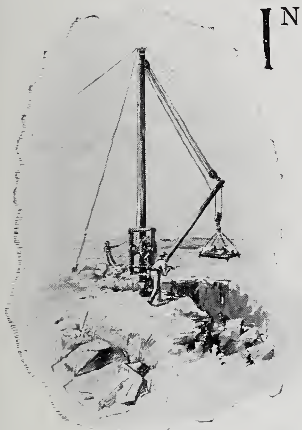
It may be objected that electricity is

now more expensive than gas for lighting purposes, and that, whatever the merits of the case, large corporations are not influenced by philanthropy and will continue to get all they can for service. Fortunately for the public the self-interest of large light, heat, and power corporations in great cities points to cheaper rates for electric energy, as surely as do the possibilities of production. Isolated electric plants continue to operate an increasing proportion of electric lamps; public supply stations want this load, and they are going to have a large part of it. The only lever, however, with which to move out the isolated electric light, heat, and power plant is a low rate for electric energy and a low rate for heat and power gas from central stations.

THE INCREASING PRODUCTIVENESS OF LABOUR

A RESULT OF INVENTION

By Francis H. Richards



IN former times industrial advancement was a matter of degree; some builded better than others, but all worked by the same general methods and employed substantially the same means. Now the car of progress runs in new channels. The agencies by means of which advancement is now effected are largely new in kind; invention has come to the rescue of the labourer.

Apropos of this, the writer, in a recent presidential address before the American Association of Inventors and Manufacturers, remarked that resources and privileges formerly undreamed of by the labouring classes have become a common inheritance. For instance, from being an exceptional event,—a thing permitted to the few,—travel has become common. The railway and the steamship have given people of every race and degree a broader acquaintance with each other, with the natural result of increasing friendship among individuals, communities and nations. Education, in a broad and true sense, has become equally general, giving the power of advancement to those formerly held in the bondage of ignorance and incapacity. Under such influences competition is becoming less and less a mere struggle for existence, but rather an emulation in the achievement of useful results. A long step has been taken toward the final accomplishment of that ancient command, "Inherit the earth and subdue it." All mankind are naturally qualified in some measure for the gradual development of their faculties and abilities, for that promotion, step by step, from one vocation to another, which has become not merely a privilege, but a positive necessity. It is no longer possible, in progressive nations, for the labourer to maintain a *status quo*.

Education properly includes both learning and training, all experience whereby one's powers are extended and disciplined; it continues through life and is not restricted to the period of youth. It has become the duty of every one to learn something more every day. This, perhaps, suggests the true reason for the decadence of the apprentice system,—a change which, after all, may be merely the extension of a truer appren-

ticeship to the whole duration of one's working years.

Not so very long ago all labour was classified as skilled or unskilled. Above the skilled labour zone, on the one side, were the professions, with an impassable gulf between; while below were the peasantry classes, untrained and non-progressive. All this has changed; the wide chasm has been bridged. The labourer, possessing both skill and training, now exercises professional powers; he stands shoulder to shoulder with—in every just sense the equal of—the professional man and the scholar. Professions and trades, handicrafts and vocations, have been multiplied and a new classification of labourers is necessary. Can we not fairly designate them "professional, expert, skilled, trained, untrained?

The march of invention constantly draws the more skillful classes of workers into new fields, and thereby furnishes the opportunity through which the less skillful classes can advance into higher occupations. A new industry necessarily draws operatives from the old and naturally attracts them, first, from the more intelligent and progressive classes of workers. The void thus created is filled by the promotion of those who, from want of intelligence, experience or discipline, were not available for the new requirements. This process, once started, must continue down through every grade and class, until all share in the general advancement and until, finally, the idle races of the world,—even the barbarian and the savage,—shall become enlisted in the industrial armies of civilisation.

At no time in history has industrial progress been so rapid or general as within the last thirty-five years. During this period a revolution has taken place greater in extent and more far-reaching in its beneficial effects than was ever accomplished by wars or conquests. Industry and commerce, supplied by invention with new resources, have advanced at a rate hitherto impossible; their forces have grown from mere squads to battalions and armies, in which great numbers of workers of many classes and capacities have been brought from a condition of uncertain employment and destructive competition to an economical and effective co-operation.

Not only has skilled labour become more productive, but unskilled labour has been made more available, through improved machinery and better administrative methods, in carrying on manufactures of nearly every kind. This, indeed, is one of the signal triumphs of this century,—the effective utilisation of that vast resource which in earlier times went to waste,—the energy of the unskilled masses.

Invention, by the creation of new instrumentalities, has opened the door of opportunity, and has brought to the homes of the artisan and the peasant advantages formerly beyond the reach of prince or potentate. If capital is merely the accumulated product of labour, then education and skill are among the highest forms of capital, for they are acquired at the cost of much labour. And, also, the immense fund of inventions already accumulated is a principal item,—if not the principal one,—of the vast capital now employed in the service of mankind.

The secretary of one of the most progressive manufacturing companies in the United States, George Otis Draper, says, with relation to the efficiency of labour in the cotton industry:—

"In spinning the product of the machines has practically doubled in the last thirty years, and the capacity of the operative has not only doubled with the machine, but has trebled or even quadrupled. The improvement has been of such a nature that the increase in speed has been attended with benefit to the product. In weaving, the product per operative has easily trebled; it is certain that the product per operative in other departments of a cotton mill has at least doubled.

"Formerly a weaver tended but one loom, and that at a moderate speed. To-day weavers on the Northrop looms often tend 24 machines running at a speed nearly double that of the original power looms. In some lines a weaver

still tends only one or two looms. In 1895, when the Northrop loom was first introduced, the maximum of an operative on common looms was represented by eight."

In the printing art the progress made is equally remarkable and extends to every department of business. The telegraph and telephone bring the news with lightning speed from every quarter of the globe; complex mechanisms reduce it to "composition" and turn out the forms for "perfecting" presses, which run off immense editions of newspapers that are quickly distributed by railways and pneumatic tubes throughout the cities and villages of the land.

During the last decade of this century the type composing machine has finally reached commercial success. Of the leading machine, and the results of its introduction, Philip T. Dodge, Esq., president of the Mergenthaler Linotype Company, of New York, writes thus:—

"With reference to linotype machines about five thousand are in use in America. The machine is wholly automatic in its operations, being controlled by a single operator at the keyboard, and produces ordinarily as much composition as four or five hand compositors, while some operators produce steadily as much matter as six good hand compositors.

"The cost of machine composition varies under different conditions from 25 to 65 per cent. of the cost of hand composition. A net saving of 50 per cent. in the cost of composition is very common. The result of the cheapened composition has been a vast increase in the quantity of printing done, with a corresponding increase in the number of men employed, in the demand for presses, paper, ink and other articles entering into the printing business.

"So far as the workmen are concerned, the introduction of the machine has been beneficial. There are as many compositors employed to-day as there were before the introduction of the machine. The average hours of labour have been lessened from 10 to 20 per cent., and the wages paid for these shorter hours are from 10 to 25 per cent. greater than they were in the days of hand composition. In other words, the effect of the machine has been to cheapen and increase the amount of printing, to give employment to a greatly increased number of men, and to shorten the hours and increase the wages of the compositors."

As to the effect of modern explosives, a well-known engineer and manufacturer of Scranton, Pa., Colonel H. M. Boies, president of the Moosic Powder Company, furnishes this statement:—

"The consumption of powder in mining has increased during the past twenty-five years at even a greater ratio than mining itself. Many public works already accomplished would have been commercially impracticable except by the use of powder of a greater power and the ability of manufacturers to furnish it at a less cost. The cost of such grades of powder as are employed, for instance, in coal mining has been very largely reduced. Within the past twenty-five years what are known as 'high grade explosives,' composed of nitroglycerine and other compositions, have been made commercially practicable by Nobel and others, and have so reduced the time required for great engineering works as to render many of these later projects commercially possible."

One of the best known envelope manufacturers, William H. Prescott, of Rockville, Conn., furnishes an account of the gradual development of the envelope business, from which I make this extract:—

"The use of envelopes was very limited previous to 1855. About this time Milton G. Puffer, of Vernon, Conn., patented a machine performing the work of five girls, as compared with hand labour. This invention was considered a great curiosity and for a few years was very profitable. About 1862 George H. Reay, of New York, made an improvement which gradually superseded the Puffer machine and performed the work of about seven girls.

"Later, about 1866, the Berlin & Jones machine was brought out in New

York. It had a device for putting the gum on the sealing flap, did the work neater and better, and performed the work of about ten girls. A few years later this machine was largely superseded by the Leader machine, brought out by Lester & Wasley, of Norwich, Conn. This machine performed the work of about twenty girls, and is one of the principal machines in use at the present day, although most of the patents on it have now expired.

"The next envelope machine of note was the Richards invention, which gummed, printed, folded and counted the envelopes, delivering these upon a table in completed bunches of twenty-five envelopes, with a band around the bunch. These machines perform the labour of about thirty girls. The consumption of envelopes in the United States amounted in the year 1899 to about 6,000,000,000."

A prominent Ohio manufacturer of twist drills, J. D. Cox, Jr., of the Cleveland Twist Drill Company says:—"Beginning in 1876, the firm with which I am connected found that with the appliances then used they could make only a very moderate profit. The writer took up the question of improved appliances, as you know, about the year 1880, introducing machines in every department,—some of your invention and some of the writer's,—the sole object being to reduce the amount of labour and not considering the cost of the machines. The selling price of our class of goods has been reduced more than 60 per cent. during the past twenty years, all of which I can say without hesitation has been accomplished by the introduction of labour-saving machines and appliances."

These reports come from gentlemen of wide experience in their respective lines of business. Their conclusions can, therefore, be safely accepted as being reliable. Their testimony is, in fact, conclusive.

Current Topics

All experience thus far with electric power for shop service has gone towards establishing the fact that electric motor installations are money savers. The friction of long lines of main shafting and sometimes of subsidiary shafting is avoided, and this, as has become well known, represents a very substantial portion of the total power ordinarily consumed. With its elimination, the power required to operate an establishment has been known to come down to astonishingly low figures, in one recorded instance being only about 26 per cent. of the actual rated motor equipment of the shop, while in another it

barely exceeded 15 per cent. of the shop capacity, even though in this the power necessary for an electric crane had been included, and that required for lighting. It is interesting to note in connection with this that in the extensive establishment of the Baldwin Locomotive Works at Philadelphia, with electric motors in service requiring collectively 3500 horse-power, the generator capacity provided is only 1550 horse-power, and of this, too, a 250 H. P. unit is kept in reserve, leaving only 1300 horse-power in service. Of the motor equipment 400 horse-power are said to be constantly idle or undergoing repairs, so that the final proportion is 1300 H. P. in the generators to 3100 in the motors, or about 1: 2.4. According to one authority, one-third of the rated motor capacity will usually be ample for the generator capacity in large plants; according to another, one-sixth has been found sufficient. These proportions obviously require qualification for different conditions, but they all help to bear out the truth of the original proposition as to the economy of the new order of things.

The famous little *Turbinia*, the first steam-turbine-driven torpedo-boat ever built, will have to look to her laurels. As it is, her hitherto unrivalled speed of 35 knots has been surpassed by the destroyer *Viper*, of H. M. Navy, another turbine boat, with 35½ knots, or practically 41 miles an hour, and there is promise of something still higher. In the *Viper* we have a vessel of 210 feet length, 21 feet beam, and 350 tons displacement, with a total indicated horse-power of 11,000, or nearly 31½ H. P. per ton of displacement. Compared with this it is interesting to note that in some of the latest of the fast Atlantic liners, with at least one of which an average speed of 23 knots is expected, the ratio of displacement tonnage to indicated horse-power is in the neighbourhood of 1: 1½, so that, size for size, the *Viper* carries approximately twenty-one times as much power as these. In this circumstance is found a substantial explanation for the phenomenal speed recorded. The latter is official, and the photograph as well, which is reproduced on this page.

THE TURBINE-DRIVEN TORPEDO-BOAT DESTROYER "VIPER" MAKING 35½ KNOTS, THE HIGHEST MARINE SPEED ON RECORD

Irrespective of all other considerations the periodically recurring agitation in favour of the compulsory use of the metric system ought to concern itself, but rarely does, with the all-important question of what it would cost to effect the proposed change in the varied industries in which the inch, and foot, and pound, and other measures of the English-speaking race have been in time-honoured service. More than twenty years ago, in a report on the subject, made to the Franklin Institute by Dr. Coleman Sellers and the late William P. Tatham, it was stated that,

according to calculation, in a well-regulated machine shop, thoroughly prepared for doing miscellaneous work, employing 250 workmen, the cost of a new outfit, adapted to new measures, would not be less than $150,000 (£30,000), or $600 (£120) per man. If new weights and measures were to be adopted, so the report continued, all the scale beams in present use would have to be regraduated and readjusted; the thousands of tons of brass weights, the myriads of gallon, quart and pint measures, and of bushels, half bushels and peck measures, and every measuring rule and rod of every description throughout the land, would have to be thrown aside, and others, which the common mind cannot estimate, substituted. The great mass of English technical literature would become almost useless, and would have to be translated from a language which we, and the nation we have most to do with, understand perfectly, into a new tongue, which is strange to most of our people. As a question of cost, let those who advocate this change consider it carefully. To the teacher, to the closet scholar, to the professional man, to those who never handled a rule or a measure, but use weights and measures only in calculation, it may seem merely a matter of legal enactment; but to the worker, the dealers in the market places, to those who produce the wealth and prosperity of the land, the question is a most serious one. Altogether, the ultimate benefits of the change proposed would be of less value than the damages during the transition. Those who choose to do so can use the metric system, and no one can object to it; but, for the government to require its people to use that, and no other, would be an arbitrary measure which they would be neither willing nor able to bear. With this view of the subject the most of us will thoroughly agree at this later day.

Americans have not an entire monopoly in the rapid production and despatch of manufactured goods. The British War Office recently required for immediate shipment to South Africa the following narrow-gauge railway rolling stock:—Two locomotives, five miles of railway, one mile of curved railway, 30 sets of points and crossings, 24 ballast waggons, each to carry 2½ tons; 15 eight-wheeled bogie waggons, each to carry guns and gun carriages weighing six tons; and two special bogie brake waggons. Each waggon was to be provided with brake, with central spring buffer and draw gear, and all were of new and special design. Manufacturers whose tenders were invited were asked to state the shortest time they would require for delivery, time being the chief factor in the disposal of the order.

The tender of Messrs. Kerr, Stuart & Co., Ltd., of London, whose works are at Stoke-on-Trent, was accepted, their specified time for delivery being ten working days. The order for this material, as detailed in the *Engineer and Iron Trades Advertiser*, was telephoned to the works. A small portion only of the material required for the purpose of the order was in stock at the works. The locomotives had been put down in the erecting shop three days previously, being intended for the Egyptian Government for the barrage works, and would have been finished, in the ordinary course, in four or five weeks from that date. The extreme urgency, however, demanded that every effort should be used, and the permission of the inspector for the Egyptian Government to use these locomotives having been asked for and obtained, the two locomotives were completed and tested in steam before the Inspector of Iron Structures and two other inspectors from the War Office within three days of the receipt of the order. Five miles of railway, with steel sleepers, two locomotives, and 24 ballast waggons, with steel under-frames and drop sides, were manufactured, painted, packed and loaded into trucks at the works of Messrs. Kerr, Stuart & Co., Ltd., within four working days

after the receipt of the order. The wheels of these waggons were of chilled cast iron, one of the specialties of two well-known firms in Edinburgh. The wheels made during the day by these firms were handed to the railway company in Edinburgh at 6 P. M., and were placed duly in a waggon and attached to a passenger train reaching Stoke-on-Trent at eight o'clock the following morning, where they were immediately bored and keyed upon their axles. The greater portion of the order was shipped at Birkenhead on board the steamer within four working days from the receipt of the order at the works. The balance of the order was completed well within the time named, was inspected, passed, and has since been doing service in South Africa.

WHEN to this is added the recent remarkable performance of another British firm,—the Patent Shaft and Axletree Company, Ltd., of Wednesbury,—in the building of two bridges for South Africa, to replace corresponding structures destroyed by the Boers, British engineers and contractors may well be pleased with the showing. One of these bridges is a 5-span and the other a 2-span design, the spans measuring somewhat over a hundred feet each, and the combined weights of both structures figure up to over 700 tons. The contract, which, by the way, was secured in competition open to American as well as British builders, provided that the first span should be ready for shipment within six weeks from the time of giving the order. The actual time consumed, however, was only sixteen working days, and it was expected that the remaining spans would go out at the rate of one a week. In the famous Atbara bridge contract last year, about 400 tons were delivered in four weeks, and the stir that was made by this American performance, which, in truth, was noteworthy, and deserves all the praise given to it, makes this later achievement by British builders all the more striking.

SOME measure of the important part that engineering and machinery play in modern ocean navigation is afforded by the fact that on the most recently launched Atlantic liner, the *Deutschland*, of the Hamburg-American Line, there are 68 steam-engines, pumps and other auxiliaries, comprising altogether 124 steam cylinders. The main engines, one set for each of the two screws, are of the six-cylinder quadruple expansion type, with a combined indicated horse-power of approximately 35,000, each engine driving a bronze screw, about 23 feet in diameter, on the end of a 131-foot shaft, 25 inches in diameter. Steam is supplied by 16 boilers, arranged in groups of four, with one chimney stack to each group, about 13 feet in diameter and 113 feet high. The sailor of the days of lofty spars and swelling canvas has disappeared from floating power plants like this, and his successor is the simple deck-hand, less picturesque, less useful, and yet all-sufficient.

THE cooling of buildings in warm weather, somewhat after the manner followed in warming them in winter, has frequently suggested itself as a matter of comfort, and even of economy, in the case of workshops, for example, where trying summer temperatures may seriously affect productive capacity. Except in a few cases, however, in chocolate making, for instance, where the temperature must be low enough to enable the chocolate to harden, and in making the familiar gelatine capsules in which medicines are administered, such cooling has not been practised, though exception should also be made of a few attempts to cool theatres and other amusement halls by blowing in air which had previously been passed over ice racks. But cooling dwelling houses has been an unpractised art until quite recently. In the current number of *Ice and Refrigeration* particulars are given of what has been done along this line in a dwelling in which there is a system of indirect hot water radiators, located in ducts over which air is led by natural

draught in winter. In summer water at a temperature of 60 degrees Fahr. is circulated through these radiators and the air cooled by them is distributed through the house. As a probable forerunner of many similar installations this plant is an interesting one to engineers and architects as well as to house owners who have the means to indulge in such a luxury.

THE old saying that "beauty is only skin-deep" is not applicable to steam engines. Indeed, in an article dealing with the general proposition that engine builders in Great Britain are losing markets abroad because British engines cannot compete in beauty with those of Swiss and other continental nations, the *Engineer*, of London, sums up the matter in the pithy sentence:—"A handsome steam engine is a better steam engine than an ugly one." If a steam engine made by one of the leading Belgian or Swiss firms,—and in less degree those of German and French houses,—be examined in detail, it will be found, the *Engineer* continues, that the beauty of external form may be classified under two heads. In the first place, there are curves and lines which, regarded purely as curves and lines, are in themselves beautiful; but, in the second place, it will be found that the proportions adopted and the shapes of the parts are in themselves a delight to properly appreciative eyes, and this because of their obvious fitness, their extreme mechanical propriety, their exquisite adaptation to the end which they are intended to subserve. A dashpot may be only, when reduced to its elements, a cylinder with a piston in it. But the Belgian or Swiss designer finds it possible so to proportion the cylinder and to devise the brackets by which it is fixed in its place, and so to select its place, that we see at once that nothing possibly better can in any way suggest itself; and whether the cylinder is painted, or bright, or blued, we are still impressed with the notion that it is better so than it could be treated in any other way. The foreign steam user appreciates this kind of thing, and the British steam user does not,—at all events, not enough to pay for it.

As to how far the proposition that a handsome steam engine is better than an ugly one is true in practice, the statement is based on the result of experience, which goes to teach that the designer and builder who values finish, and mechanical fitness to a required end, is likely to carry his desire for the best right through. If a connecting-rod has been carefully designed, it is not probable that a mistake will have been made in the piston. Again, it is quite impossible to get a really highly-finished surface unless the steel or cast iron is very homogeneous. There is, of course, the ordinary cheap buffed surface, which deceives no intelligent person. But it is out of the question to imagine that the splendid polish which fine steel will take can be imparted to a metal full of specks or flaws. The steel in a British connecting-rod may be superb, though no pains have been taken to give to it the high finish dear to the continental heart. But after all has been said there is no doubt that a high finish is, to a large extent, a guarantee of excellence.

IT would, however, be a serious mistake to suppose that because one engine is not so æsthetically perfect as another, that it is really worse. It is reasonably true that on the Continent fine finish is apparently essential to excellence. There only the best firms make steam engines worth having, and the best firms make it a practice to finish their machinery almost without regard to cost; so it has come to pass that external beauty is a guarantee of intrinsic merit. In Great Britain it is not so; yet, nevertheless, admirable engines are made there. Those firms abroad who have bought British engines know that they are thoroughly excellent, and have probably learned that external beauty

is, after all, not an essential concomitant of economy of fuel and exemption from breakdowns. Still the fact remains that the foreigner likes finish, and if he is willing to pay a moderate extra price for it to his own countrymen, it seems that it would be good policy to try and meet his wishes. This, of course, raises the old, old question, How much does finish add to the cost of an engine? First-class workmanship is, in the end, if not the cheapest, not much dearer than bad workmanship. But beauty of finish can be obtained at a moderate price only when it is largely made to pay for itself, and that can be secured only as a consequence of that reduction in the expenditure on labour which the use of accurate gauges and templets and first-rate machine tools confers. When a weigh-shaft has to be filed in order that the rocking arms may be made to go on, or when the arms have to depend on accurately fitted keys for their security, the cost of labour must be excessive, as compared with what is necessary when the shaft has been turned and the rocking arm bored to the templets with such accuracy that the arm can be pushed on to the shaft by hand, and yet is a dead fit. It is in this class of work that British builders have fallen behind. But they are doing better now, and may find, on trial, that in the long run finish and beauty may be made to pay.

THAT the lathe has come to us from very ancient times, that it is, in fact, the earliest form of machine tool of which there is any record, is fairly well known; but it may be a matter of less common knowledge that even to-day, as found in use among the natives of India, it remains the same primitive apparatus that it was at the probable starting-point of the art of turning. Holtzapffel, in one of his interesting volumes on "Turning and Mechanical Manipulation," shows this in a little sketch which has been reproduced on this page and which represents the common type of wood-turning lathe still employed by the native craftsman. Of its arrangement and manipulation he gives the following account:—When any portion of household furniture has to be turned, the wood-turner is sent for. He comes with all his outfit and establishes himself for the occasion at the very door of his employer. He commences by digging two holes in the ground at a distance suitable to the length of the work, and in these he fixes two short wooden posts, securing them as strongly as possible by ramming the earth and driving in wedges and stones around them. The lathe centers, scarcely more than round nails or spikes, are driven through the posts

WOOD TURNING IN INDIA

at about eight inches from the ground, and a wooden rod for the support of the tools is either nailed to the posts or tied to them by a piece of cocoanut rope. This rod, if long, is additionally supported, as shown in the illustration, by being tied to one or two vertical sticks driven into the ground. During most of his operations the Indian workman is seated on the ground; hence the slight elevation of the centers of his lathe. The boy, who gives motion to the work, sits or kneels on the other side of it, holding the ends of the cord wrapped around it in his hands, pulling them alternately. The cutting, thus, is restricted to one-half of the motion,— that of the work towards the tool. The tools themselves are almost confined to the chisel and gouge, and their handles are long enough to suit the distant position of the operator while he guides

their cutting edges by his toes. He grasps the bar or tool rest with the smaller toes and places the tool between the large toe and its neighbour, generally out of contact with the bar. It is interesting to note here that the Indian turner attains a high degree of prehensile power with his toes, and when seated at his work not only always uses them to guide the tool, but will select indifferently the hand or the foot, whichever may happen to be the nearer, to pick up or replace any small tool or other object.

THE limited supply of tools used by the Indian for working in wood is also remarkable. They are of the most simple kind and hardly exceed those represented in the sketch above. The most essential in constructing and setting up his lathe is the small single-handed adze. With this he shapes his posts and digs the holes; it serves on all occasions as a hammer and also as an anvil when the edge is, for a time, fixed in a block of wood. The outer side of the cutting edge is perfectly flat, and with it the workman will square or face a beam or board with almost as much precision as if it had been planed. In using the adze, or bassoolah, as it is called, for this latter purpose, the work is generally placed in the forked stem of a tree, driven into the ground, as illustrated.

CHARLES M. SCHWAB

PRESIDENT OF THE CARNEGIE STEEL COMPANY, LTD.

A BIOGRAPHICAL SKETCH

THE ranks of those who have won distinction in developing the American iron and steel industry to its present high state hold as one of their youngest, and yet one of their most prominent, members Charles M. Schwab, the president of the Carnegie Steel Company, Limited, of Pittsburgh. Carnegie has become a familiar name on both sides of the Atlantic, suggestive not only of progressive methods in iron and steel making, and mammoth works and output, but of huge profits as well. These tell a story perhaps more striking than anything else, and as one of the men who have helped to that result Mr. Schwab is to-day a figure of international interest.

He is a native of the State of Pennsylvania, and was born on February 18, 1862, at Williamsburg, Blair County. His remote ancestors were Germans, but his parents were native Americans. His father was a woollen manufacturer at Williamsburg for many years. In 1872 the family removed to Loretto, Pa., a little mountain hamlet on the crest of the Alleghenies, famous as the cradle of Catholicity of the western slope of the Alleghenies, and the place where the Prince-Priest, Demetrius Gallitzen, kin to the present house of Russia, struggled one hundred years ago to plant the cross and spread civilisation. Loretto is the oldest seat of religion and learning in the United States west of Philadelphia, and there, under the tutelage of the Franciscan friars, young Schwab received his sci-

entific education. When but a boy, before his college days, his time was employed on the farm and in driving the coach which carried the mails and passengers from Cresson station up to Loretto, his father having at that time the contract for carrying the mails between these points; and there are many who yet remember the president of the great Carnegie Steel Company as the smiling, courteous lad whose intelligent conversation entertained them on the four-mile drive from Cresson to Loretto.

In July, 1880, he graduated from college, and immediately set out to earn his livelihood. During the same month he engaged to take a position in a grocery at Braddock, Pa., and thus the executive head of one of the largest, industrial establishments in the world began his business career. The grocery trade, however, did not impress the young man as a promising field in which to realise his expectations, and when, after two months' experience behind the sugar counter, he found an opening more suited to his taste and abilities, he relinquished his position to enter the service of the Carnegie Steel Company, Limited, in the engineering department.

His ambition was to become an engineer and his beginning was at the bottom. The first duty assigned to him was stake-driving, at the Edgar Thomson Steel Works, Bessemer. But from the outset almost it was evident that Schwab was capable of eventually filling a high position in the department, and the transition in his fortune was, consequently, rapid. In six months after he entered Carnegie's service he was appointed superintendent, and in that capacity supervised the construction of eight of the nine blast furnaces now comprising the Edgar Thomson plant.

Mr. Schwab also originated other engineering works of considerable magnitude at the Edgar Thomson Works, including an addition to the rail-mill department, giving the works an output exceeding any mill in the world. The changes made at that time, with improved blast furnace and steel conversion practice, effected such large economies in manufacturing cost as to make competition possible in the markets of the world, to the extent that the product of this mill is now to be found in every quarter of the globe where railroads are operated.

He continued as superintendent and assistant manager of the Edgar Thomson Furnaces and Steel Works from 1881 to 1887. The late Captain William R. Jones, whose enduring works must ever be associated with the early development of the American steel industry, was general manager of the plant at that time, and showed abiding faith in the genius and capacity of his assistant. Mr. Schwab co-operated with Captain Jones in the perfection and practical demonstration of the invention known to the steel industry as the "metal mixer," which has made the name of Captain Jones almost as famous in the world of metallurgy as that of Bessemer, Siemens, Martin and others.

In 1887 Mr. Schwab was appointed superintendent of the Homestead Steel Works of the Carnegie Company, and reconstructed the entire plant, making it the largest plant in the world of its class, producing steel blooms, structural shapes, bridge steel, boiler, armour, ship and tank plate, and steel castings. Shortly after he assumed the management of the Homestead Works the Carnegie Company undertook the manufacture of armour plate at the request of the United States Navy Department, and the success attending this great enterprise from the first day of operation may be attributed to the engineer's clear perception of the mechanical and metallurgical difficulties involved, and the manner in which he overcame obstacles in this gigantic work.

No branch of the steel industry presented in its inception such hazards to the engineer and steel maker as did armour plate making, and the results accomplished by Mr. Schwab were particularly creditable from the fact that he succeeded almost from the initial effort, whilst every previous attempt failed at the beginning and armour was not pro-

duced successfully until after a long period of experiment.

Mr. Schwab remained at Homestead as superintendent until October, 1889, when, upon the death of Captain Jones, resulting from an accident at the Edgar Thomson furnaces, he was appointed general superintendent of the Edgar Thomson Works and furnaces. In 1892 the Homestead Steel Works were also placed under his management for the second time, and, with headquarters at Homestead, he directed the operations of both immense establishments, employing thousands of men and producing several million tons of steel per annum. He was elected a member of the board of managers in 1896, and in February, 1897, he succeeded John G. A. Leishman, United States minister to Switzerland, to the office of president of the vast Carnegie enterprises.

This, in brief, is the record of Charles M. Schwab's career, from the country lad on the driver's seat of the mountain village mail-coach to the president's chair of one of the leading commercial institutions of the world. His life of less than two-score years has, indeed, been remarkably successful, and is all the more creditable since he owes nothing to advantageous circumstances of birth and exceptional opportunities; but, unaided, and by the merit of his own efforts, he has attained a foremost place among the leaders of industrial commerce of the world. His achievements have been many and noteworthy, and, as a mechanical and metallurgical expert of the Carnegie Steel Company, he has been an important factor in the success of that establishment. Mr. Schwab's services to the iron industry are highly valued, and many of the rolling mill devices and steel works improvements now employed on both sides of the Atlantic are the product of his genius. He holds membership in various scientific and industrial organisations in America and Europe, including the American Iron and Steel Association, the American Institute of Mining Engineers, and the Iron and Steel Institute of Great Britain.

Mr. Schwab's personal characteristics are strikingly forceful. He shows keen and certain judgment, and a manner openly frank and unassuming; but the predominating trait of his nature is gentle, affable and sympathetic temperament, which wins admiration and friendship.

Appreciating the necessity of training the youth of to-day, that they may be self-dependent in after life, Mr. Schwab founded in Homestead a free polytechnic school in which instruction is given in mechanical drawing, rudimentary engineering and kindred practical studies. The school is conducted as a branch of the Pennsylvania State schools, and it has met with such gratifying success that the founder now contemplates building and equipping a training school for girls. His beneficence has been well applied in this undertaking, as well as to numerous worthy charities which he supports generously, though quietly.